WARMING BUILDINGS
BY HOT WATER

A PRACTICAL TREATISE

UPON

WARMING BUILDINGS BY HOT WATER

EMBRACING METHODS AND APPLIANCES FOR WARMING BUILDINGS OF EVERY DESCRIPTION

INCLUDING

ALL LOW-PRESSURE SYSTEMS, THE HIGH-PRESSURE SYSTEMS, HEATING DRYING ROOMS, AND WARMING BUILDINGS BY HEATED AIR

BY

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PREFACE

THE aim of this book is to provide an exhaustive treatise on the subject of Warming Buildings by Hot Water; describing all recognised "systems" of piping, all methods adapted for particular purposes—such as residence work, the treatment of larger buildings, of places of worship, factories, horticultural glass-houses, &c.—and added to these a full description of the fittings and appliances required. Although included in the foregoing general terms it may be separately mentioned that the High-Pressure system, with or without valve, is fully treated—more so than hitherto; and, as the subject is too short for a separate treatise, a chapter of twenty-six pages has been devoted to Warming Buildings by Heated Air. Although this latter subject is included in the one chapter, it is fully dealt with, all possible opportunity being taken to illustrate the details, as in the other parts of the book, and to give practical tables to work to.

One of the early chapters will be found to deal with the advantages of warming buildings, particularly residences, by hot water. This cannot be considered a practical part of the book, but is given in the belief that it may be helpful to those who pursue the trade. It will put into their mouths a catalogue of the many real benefits that this mode of heating affords, and may in season enable an engineer to secure a wavering customer. The author has lived for many years in

houses heated by hot water, which enables him to describe what really remarkable benefits hot water as a heating medium affords.

Another early chapter is devoted to a fully detailed description of a simple form of hot water apparatus, this being given with the view to enabling a novice to read the matter up from its elementary beginning. Failing this the book might be considered as suitable only for engineers of some experience; and, as stated, the idea has been to include an elementary chapter for the beginner.

Amongst other details is included what is new in a treatise on this subject, viz., information, and a table, enabling heating plants to be tested in any winter temperature other than that which figures in the guarantee embodied in the contract. This was the substance of a paper read by the author before the Institution of Heating and Ventilating Engineers and awarded their medal.

In regard to boilers the author has not found it necessary to alter the new table of actual heating values he set up in the earlier editions of Hood on Warming Buildings, and although boiler makers have not, as yet, based their calculations on figures quite as low, there is no gainsaying that they might with advantage do so. It is everywhere recognised, even among themselves, that something should be done, and will eventually be done, to give boilers more precise catalogue values than they now have.

Owing to the wide degree of misconception that exists regarding the effects of heat in Drying Rooms, this subject is given a chapter with the view, not so much to show how heat can be afforded in such places, as to make it clear how it can be utilized with advantage. The chapter is largely devoted to showing that heat by itself has no drying qualities

—that to heat goods in a closed room will not dry them. There must be ventilation, for it is air that is the drying agent and the warmer the air can be made the more thirsty it will be. The best results are therefore obtained by heating air and causing this to pass through the rooms in a continuous stream, circulating past the moist goods and then (after absorbing moisture) to pass away.

Finally it may be said that this treatise, which is wholly new matter, is intended to supply a less expensive book and one that is less of a text-book than Hood on Warming Buildings, and which has hitherto been the writer's recognised work.

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WARMING BUILDINGS BY HOT WATER.

CHAPTER I.

THE LAWS OF HEAT, ETC.

THE sensation experienced when approaching or touching anything of a high temperature, was originally attributed to the action of some subtile material, matter or fluid, which pervaded all hot substances; this delicate material being impalpable to our vision, and all our senses except that of feeling. This was known as the Material Theory. Now it is quite decided and recognised that heat is only a peculiar manifestation of motion—a minute but rapid movement of the particles (molecules) of which all descriptions of matter are composed. The rapidity with which the particles move is the index to the temperature; the more rapid the movement, the greater the heat, while a less rapid action manifests a less degree of warmth. This is known as the Kinetic (motion) Theory. Put briefly, we may say that this theory is based on the fact that by motion heat may be produced (the friction of a machine-bearing, if not oiled, proving this), while by heat we may produce motion, both directly and indirectly.

Heat transmits or manifests itself in three ways, viz. by—

1. CONDUCTION.
2. RADIATION.
3. CONVECTION.

All three actions intimately concern the heating engineer, and a knowledge of them is essential for the proper understanding of heating works of all kinds.

I. THE CONDUCTION OF HEAT.

This action may be said to be confined to solid materials. Fluids, both liquids and gases, possess conductive powers in a degree ; but it will be seen, by studying the subject of CONVECTION, that fluids cannot successfully utilise any conductive properties they may have. Air, in fact, ranks as a poor or bad conductor.

Materials are said to be good conductors or poor conductors according to their heat-conducting powers ; and these terms have the plainest of meanings when it is known that no two materials, of the vast number that exist, have exactly the same powers in this respect. The term "non-conductor" is a misleading one, as nothing exists that is totally devoid of the conductive property, and it would be well if this term had no existence in the heating engineer's mind.

The Conduction of Heat is that action which causes heat to travel along, or through, a solid substance which is not exposed to heat at all parts. A familiar example may be quoted in noticing what happens to a length of rod iron when it has one end thrust into a fire. It may have been icy cold when put in, but in a brief time the end which is outside the fire is unbearably hot, even though it may be shielded so that the fire does not shine on it. The heat has travelled up the rod, from the end in the fire, by conduction. A more interesting example may be seen in an ordinary heating boiler. If the metal of which it is composed was not a conductor of heat, it is obvious that the heat from the fire would not be transferred to the water. In the same way if the heat contained in the water within a radiator found a barrier in the iron of the radiator, then no warmth could escape or be distributed into the room or place where the radiator might be situated.

The transmission of heat by conduction varies in different materials, as stated ; but fortunately iron, a cheap metal, is a good conductor, sufficiently so to make iron boilers and heating appliances highly successful. The table most usually

relied upon for the comparative values of materials in heat conduction is that of Despretz, which is as follows:—

Silver	97·3
Copper	89·8
Brass	75·2
Cast iron	57·0
Lead	18·0
Marble	2·3
Firebrick	1·1
Water	0·9

A better known authority in England is Thomas Box, whose treatise on "Heat" is a recognised standard work, and his table (abbreviated) is as follows:—

Copper	515·0
Iron	233·0
Zinc	225·0
Lead	113·0
Marble	28·0
Brickwork	4·8
Indiarubber	1·8
Coke dust	1·3
Woods (average)	1·0
Chopped straw	0·6
Ashes	0·5
Sawdust	0·5
Cotton and sheep wool	0·3
Eiderdown	0·3

This table, it will be noticed, affords information as to the comparative values of poor conductors, showing what a high resistance to heat-transference (which means heat-loss in certain cases) some materials exert. Silicate cotton, which is a material largely used for covering pipes and surfaces with a view to preventing loss of heat, would rank as 0·3 in the table just given; while hair felt, which is made of cow and horse hair, would rank as 0·3 also. In other words, these two materials are the best known materials we have, easily obtainable, to prevent loss of heat from hot surfaces. It will be recognised that while a hot-water heating apparatus is specially designed and erected to lose heat in rooms, yet if it

loses heat anywhere else the loss must mean wasted fuel. In other words, every effort is made to make the apparatus part with its heat in the rooms and places to be heated, but nowhere else; and this makes information relating to poor heat-conducting materials useful.

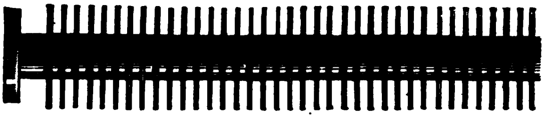


FIG. 1.

There is a peculiar property relating to the conductivity of iron now to be considered, as its application is somewhat general. This property has been termed "diffusivity," meaning the power that metals have of diffusing heat over or through a large area of their substance. It is only another name for conduction, but the action bears a different application. If we take a hot-water pipe and fill it with water at, say 180° F., the heat of its outer surface will be practically the same temperature. But if we add a number of solid gills to the pipe, as Fig. 1, the heat will quickly travel into these plates and so become diffused over a much greater area. It must not be thought, however, that the whole will become of a temperature of 180° F., and it will be found that with the increased area there is a decrease of temperature. In other words, we get a large surface area at a moderate temperature, instead of a much smaller area of surface at a high temperature. The total number of heat units (see page 17) afforded from the surfaces in either case might be considered as the same, but with the larger surface a greater volume of air can be warmed, as the small intensely hot surface is made into a larger surface at a more usefully effective temperature.

A familiar instance of the utility of gills or feathers attached to hot surfaces may be cited in what is usually called the Gill-Stove. This is a cast-iron stove built up of sections, but forming in reality an arched-top shell stove with gills about $\frac{3}{4}$ inch apart all along the exterior. It has no firebrick

lining, so that the part nearest the fire—the shell—would quickly be at a red heat; but the gills take up the heat, and by diffusing it throughout their large surface (they project about 6 inches from the shell) the temperature is not dangerously high, while the surface for warming the air and surroundings is at least six times as great as a plain stove could have.

The gilled pipe shown in Fig. 1 is largely used in Germany for hot water and steam work, but it is a little difficult to see the advantage with hot water as the heating medium, for the temperature of a plain pipe is not too high, and to reduce it at all materially would do more harm than good. The heat of steam may bear a little reducing, though not much. Gills, or similar solid projecting parts, are of service on pipes, and what are termed indirect radiators, when it is required to stack them closely, expressly for air to pass through rather swiftly, yet to be warmed. The spaces between the heating surfaces must not be large if air is to pass through rapidly and yet be warmed. Indirect radiators are used for fixing in boxes, or other enclosed spaces; these boxes having cold air inlets and warm air outlets, the latter leading into the rooms or places to be warmed. The warmth is thus obtained wholly

FIG. 2.

by warmed air; and to ensure the air being warmed, the radiators are so constructed as to compel the incoming cold air to rub against the hot surfaces. Fig. 2 shows such a radiator, and it will be seen that, enclosed in a moderately close-fitting box, it would be difficult for air to get through

without being raised in temperature.* Therefore, it may be considered that gilled pipes or surfaces in hot-water works are intended, not to reduce temperature, but to break up and reduce air passages between otherwise plain and open heating surfaces.

It will be understood that these remarks relating to diffusivity only apply to solid gills or projecting parts. If gills were made hollow, so that the heated water (or gases from a fire) could enter and work through them, they would then be of the fullest temperature throughout, and no diffusive action would have to be considered.

II. The Radiation of Heat.

The radiation of heat is an action that entirely differs from that of conduction, in that it is the projection of heat rays through the air from the outer surface of the heated object. It would be more correct to say that the rays pass between the particles (molecules) of which air is composed, for radiant heat has the peculiar property of passing through the air without warming it. This heat travels from every hot object in rays or beams, these travelling in straight lines, and their heat is only manifested when they strike on a body or object. Thus, if we stand in front of a fire, we become warm by radiant rays striking us, but they only strike on the side facing the fire. If a screen is interposed, the rays are no longer felt; nor are they if the body or object is in any part of a room out of sight of the fire. A further familiar example can be given in pointing out how the shade of a tree prevents the sun's heat being directly felt, and the same example exists in the use of a lady's sunshade. These show that the rays have to actually strike against an object to warm it, also that these rays travel in straight lines, not bending or travelling round any obstacle coming in their path.

It may be further explained that radiant heat-rays diverge or open out as they leave their source, or, more correctly

* The projecting parts are not always gills. In some cases they are pins, or other shaped projections, but all are intended to serve the same end.

stated, their intensity diminishes as they reach further from their source. This loss of intensity is inversely as the square of the distance, and Fig. 3 will make this clear. It will be

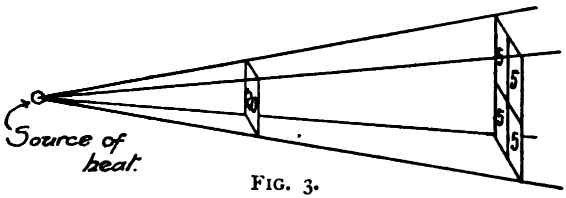


FIG. 3.

seen that as the rays leave their source they affect a larger area, but this area is of a less intensity as to temperature. It is this action that accounts for our feeling the heat increase in intensity as we move nearer to a fire, or of less intensity as we get away from it.

It might naturally be thought that if radiant heat fails to warm the air, then the air of a house (heated by fire-grates only) would always be extremely cold in winter weather; whereas we know by experience that, after a few hours, the air in the rooms of such a house becomes comfortably warm. This is due to the radiant rays striking against the walls, floor, articles of furniture, etc., and these, when warm, cause the air which has contact with them to be warmed. In such a house, therefore, the warmth in the air is derived from its having touched objects which have been heated by radiant rays. The action of air on becoming warm is the subject of the third division of heating—viz. CONVECTION (see page 10).

Although the radiation of heat from red-hot bodies interests the heating engineer in its relation to boilers and furnaces, the radiation from hot-water pipes and radiators proceeds from much cooler surfaces, and has no luminous source. With non-luminous bodies the outer surfaces have much to do with the results, and it is usual, with these, to say that the rays of heat proceed from the skin of the object. On this account the nature of the outer surface of a pipe or radiator could make a marked difference in the amount of heat radiated, but, fortunately, practically all paints give a suitable skin.

The following table will serve to show how radio-activity varies with different substances and surfaces :—

RADIATING AND ABSORBING POWERS OF SUBSTANCES.

(The heat-radiating and heat-absorbing powers of materials are equal, but their reflecting powers are in inverse ratio.)

Lampblack	100
White lead	100
Water	100
Glass	90
Cast iron (natural surface)	60
Oil (film)	59
Tarnished lead	45
Cast iron (polished)	25
Wrought iron (polished)	23
Zinc (polished)	19
Silver and copper (natural surface)	12
„ „ (highly polished)	3

Metallic oxides and earths, which go to form paint, rank as good radiators, therefore, as stated, there is no colouring matter that has to be condemned. Varnish is also a successful radiator of heat. What has to be guarded against is a polished surface; and, although the writer has no test figures before him, yet everything points to bronze powders being poor radiators of heat. In conducting some experiments, however, it was found that a coating of lacquer or varnish completely altered the radiating qualities of a polished surface, making it rank but little below a painted surface.

The painting and general decoration of radiators will be found treated in a later chapter; but it will be seen that, while plain cast iron is a good radiator, it can be actually improved by being painted.

Having devoted space to the description of radiant heat and its qualities, it is now necessary to point out that this subject is of much less importance than it appears. Perhaps it should be said that radiant heat does good and active work from the glowing fuel in boilers, but the amount of heat it gives into rooms heated by hot-water pipes and radiators is

comparatively small. The term "Radiator," which is given to the heating appliance bearing this name, has the advantage of sounding well, and it also does something towards making hot-water work appear very hygienic and health-giving (as it really is); but if we had to rely wholly on the radiant heat given off by hot-water radiators (or pipes), then this mode of heating would be expensive and objectionable, on account of the size of the radiators required for even fair results.

Let it be clearly understood, that a hot-water apparatus affords warmth chiefly by warming the air. It is doubtful if any authority has been able to state what proportion the radiant heat bears to convected heat (see p. 10) in the total warmth afforded by radiators or pipes; but if radiant heat is credited with one-fifth of the whole (warmed air four-fifths), it is giving the radiant heat the best possible value. It is practically impossible to obtain radiant heat from these surfaces without heating the air of the room, otherwise a test could easily be made, but a thermometer fixed 24 inches in front of a radiator, and one fixed 24 inches above (in the stream of heated air rising from it), show very different results. Again, quite a marked decrease in the warmth of a room is experienced if a very loose-fitting shallow open box is inverted and placed over the top of a radiator, to retard the rising current of warmed air from it. Or, if a radiator is carefully surrounded at sides and top with a wood casing, and a strip about 4 inches high fastened across the lower part in front, thus leaving only the front of the tubular part of the radiator exposed, it will prove a very inefficient heater. As will be seen, this device prevents, as far as possible, a flow of air up through the radiator, though it makes but little difference to the heat radiated from it.

The average engineer considers that this information should not be too freely discussed, as there is a strange prejudice in the public mind against warmed air. Radiant heat is more in demand, the public not knowing that this form of heat might prove uncomfortable. It certainly would alone. Take the evening of a summer day, and note what it is that makes the temperature—the atmosphere, everything that

our senses experience—so very agreeable. It is not the sun, for that has set. There is some radiant heat from warmed objects, but no greater proportion than that given by a hot-water radiator. It is warmed air that is so agreeable; it pervades all space, the source of heat not being from one point but from all points, for the earth, walls and all things the sun has shone upon during the day are now acting as low-temperature radiators. It is by no means an exaggerated analogy to consider the hot-water boiler as acting the part of the sun, for both afford the ultimate heat—the warmth we feel—by the same means when the sun is not visible. Both cause objects to distribute warmth, a little by radiation, but mostly by warming the air. The air is not warmed by the sun, but by the objects heated by the sun. If we relied on radiant rays alone, then we should be bitterly cold. If people ascend to a great height in a balloon, they are approaching a little nearer to the sun than those on the earth, yet the nearer they get the more likely they are to be frost-bitten by the intense cold, even though the sun be shining brightly all the time.

III. The Convection of Heat.

The subject of Convection (*conveho*, to carry up) deals wholly with the action of heat upon fluids—air, gases, and liquids. The action of convection largely ceases, however, when liquids boil, that is, it is interfered with; but of course the water in a hot-water heating apparatus is not required to reach boiling point, therefore this detail does not require special consideration.

To understand this action, which is a peculiar one, and of chief importance to the hot-water engineer, it is necessary to inquire into the physical properties of liquids and gases. First, it must be explained that all fluids exist in the state of a mass of exceedingly minute particles, which are termed molecules. These are said to possess the property of mobility to a very perfect extent, as they are able to move up, down, or around one another, absolutely without resistance or friction. No one has seen a molecule of water or air; but from

the property just stated it might be assumed that they are round, like minute ball-bearings. Even with polished steel balls it is possible, with care, to pile them up a little, yet no one can get a pile of water, however small. Some authorities have argued that a repelling influence must exist amongst the particles, as both water and gases, if free to move and spread out, always cover the utmost possible space, and readily separate into distinct globules. This scarcely interests the heating engineer, except that it shows what an absence of friction there is amongst the molecules of which water and air are composed.

Assuming, therefore, that a vessel of water is in reality a vessel containing a vast number of minute liquid particles, let it next be seen what happens to these particles when heat is applied. In this the student is strongly recommended to make the simple experiment here described. Take an ordinary glass jar, place this on a stand, or suspend it by a string, so that there is room to place some kind of lamp beneath it. Nearly fill this jar with water, into which has been stirred some amber-dust—or the fine saw-dust of a hard wood, such as walnut, mahogany or oak will do. If much of the dust collects at the top, skim it off, as there will be plenty left suspended in the water to show any movement that occurs.* Place a spirit lamp or an oil lamp, as Fig. 4, beneath the jar at one side, and watch the water. It will be found that a movement occurs almost immediately, the particles over the lamp ascending, while those on the more distant side descend; and a constant circulatory movement is set up, and continues as long as the lamp is alight. If the lamp is shifted to the other side the movement will gradually, yet swiftly, reverse itself. If the lamp is placed centrally under

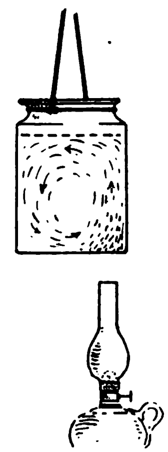


FIG. 4.

* It must be explained that water in glass vessels or pipes is invisible, and any movement in the water equally so. The particles of amber or wood enable any movement that occurs to be readily seen.

the jar, the ascending movement will be in the middle and the descending movement round all sides.

Several things may be noticed from this simple experiment. One is, that the water commences to move at almost the same instant as the lamp is placed beneath. Considering that the bottom of a jar is thick, and that glass is an exceedingly poor conductor of heat,* it is remarkable how soon the water commences to move. It goes to show very clearly that quite a minute difference in temperature is sufficient to set up the circulatory movement—the action of convection. This should be particularly noted, for there is a common impression that this movement cannot always be obtained. A man says he cannot get a circulation in his pipes, and supposes that the boiler is not powerful enough. This must be wrong, as quite a trifling difference in temperature will set up a strong movement; and it may be said that a real difficulty should be experienced in preventing the water circulating, once it is warmed. It may be taken for granted that a very little heat will cause a good and free circulation to set up if the general conditions are correct and favourable. A few minutes expended in the simple experiment suggested will prove this.

The theoretical explanation of the action of convection is this: when heat is applied to the bottom of a vessel containing water (or any fluid), those particles nearest the bottom of the vessel absorb heat, i.e. they become warm. Practically everything in nature expands and becomes of greater bulk when warmed, and the particles of water are no exception to this rule. Therefore, when heat is applied to the bottom of a vessel of water we may imagine the particles nearest to the bottom increasing in size. This increase in size is not accompanied by any increase in weight, consequently the expanded particles become lighter, bulk for bulk, than the colder ones above. So soon as this happens it follows that the warmed particles must rise, for no substance lighter than cold water can remain at the bottom of a vessel when cold water is

* If a strip of glass, only four inches long, is taken in the fingers by one end, while the other end is held in a gas flame until it is red-hot, the fingers will experience no disagreeable degree of heat.

above. Supposing a piece of cork were plunged to the bottom of a vessel of water, would it remain there? it could not, because, bulk for bulk, it is lighter than water; and the particles of warmed water may be likened to particles of cork, for they must, on account of their lessened weight (compared with their bulk), rise to the top.

It is most important that the true action that occurs should be recognised. There is a too common impression that heated water rises of its own accord; that the heat gives it some power to rise. It is nothing of the kind. If heated water is put into a glass, it does not rise and flow over the sides. *The only cause of heated particles of water taking an ascending course is the superior weight of the cooler particles.* These cause the heated particles to ascend, and were this cause absent the hot water would rest quietly where it was heated.

To prove this explanation to be correct the action can be reversed if desired. Fill a glass vessel with warm or hot water, having amber or wood-dust in it to make any movement visible, then apply a piece of cold iron or ice to the top of the water and note the results. There will be a circulatory movement much the same as with the previous experiment, but it will be due to the cooling of the top water,* and not the heating of the bottom water. If the source of heat or cold is applied in a reverse way—that is, heat to the top of cold water, or cold to the bottom of heated water—no circulation will occur.

Air acts in precisely the same way as water when it is heated, except that it moves even more rapidly. As stated when dealing with the subject of RADIATION, it is the warming of the air by radiators or pipes that accounts for the pleasant degree of warmth obtained. Radiant heat, though good to talk of, does little work from radiators or pipes. It does some of the best work from incandescent fuel in boilers, but from comparatively low-temperature surfaces it does little. As stated, radiators warm rooms by radiant heat and convected

* The falling of cool air at windows is due to warmed air coming in contact with a cool surface.

heat (the heating of air), but the proportion is at the best only about 1 of the former to 4 of the latter. It is therefore highly important that the circulatory movement of warmed air from radiators and pipes should be assisted and made effectual by every possible means.

What has to be aimed at is the quickest and most even distribution of the air that is warmed; and no mechanical aid is required to effect this if the warmed air is allowed to circulate freely (as it readily will) and no obstacles to the movement are allowed to exist. To obtain this, it is requisite that air shall have free admission to the hot surfaces, particularly beneath them, and that the air when warmed shall be allowed

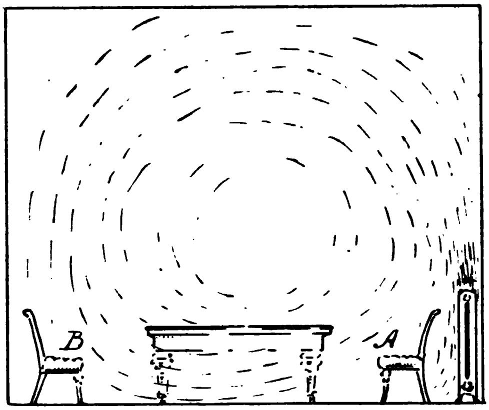


FIG. 5.

to rise freely from the top. Radiators are best without ornamental tops, marble or iron, on this account. The heated surfaces give much the best results if they are vertical, and this is obtained in all modern radiators. They must also be clean, and not too closely packed. With these conditions the warmth will be so well distributed that a person occupying a chair at B, on one side of a room, will experience quite as good a temperature as any one at A. Fig. 5 shows the position of the chairs, the movement of the warmed air being indicated by broken lines.

The study of air-movement when the air is heated can

be profitably undertaken, as it often influences results. It gives a correct idea as to where radiators or pipes should be fixed to afford the best and most uniform results. It will be found referred to more generally under the descriptions of example works.

The Combined Actions of Conduction, Radiation, and Convection in a Hot-Water Heating Apparatus.

In perusing the separate descriptions of the actions of Conduction, Radiation, and Convection, it will have been noticed that all three take an important part in transferring heat from the furnace to the rooms which are to be warmed, and the absence of either action would bring about failure.

Commencing at the fire, we have radiant heat performing an active part when the fuel is in an incandescent state; and, were it possible to keep the fuel in this condition, many boilers would be much more effective than they are. This, however, is not practicable, as the boiler of a heating apparatus commonly—usually, in fact—has to take a charge of fuel that will last some time without attention, and this keeps the top of the fire covered, or in a dull state, for a considerable period after each occasion that stoking is done. In large buildings and institutions, where an engineer is kept, the fires may be kept in better condition, and boilers are worked closer up to their actual power, but with the majority of heating works the stoking is of an unskilled kind, and radiant heat in the boiler only does work intermittently. As stated, when describing the action of Radiation, radiant heat from glowing fuel is a very effective form of heat-transference, but from dark low-temperature objects the radiant rays do comparatively little.

In a boiler, heat transfers itself from the fire to the plate in two ways: one is by radiation, as described, this affording heat to the surfaces upon which the fire shines; while the other is by contact. There is contact of the hot fuel, and contact of the flames (if any) and heated gases. In the case of heat

from flames and heated products of combustion, it has to be remembered that neither of these can be considered to afford much heat unless they actually touch the surfaces to be heated. They certainly give off some radiant rays, but these are of little value compared with the heat obtained by contact. Any simple experiment will show this: a piece of thin wire held close to a flame will become fairly hot, but nothing more; but if held in the flame it becomes red and then straw-colour in a few seconds.

This peculiarity of flame (and hot gases) requires consideration in flue making, for bad results are still more easily obtained by the fact that flame has a tendency to float between surfaces—to avoid touching them, if it can. Flame and gaseous heat must be *made* to touch the surfaces, and this is effected by making the flues as narrow as possible, and with as little bottom surface as can be had. A flue of this section 0 is more desirable than this o. Vertical heating surfaces are not the best, but they are much superior to a surface beneath the source of heat when the latter is a flame.

Assuming that the best has been done to cause the heat from the fuel to come in contact with the boiler plates, it has next to pass through the metal. This degree of transference readily occurs by Conduction, as will have been understood (see page 2), and it may now be supposed that the heat is on the water side of the plates. Water is a good absorber of heat (see page 8), so good that it is considered to be able to take up heat from a boiler plate two and a half times as fast as the plate can receive and conduct it. It is the action of Convection that accounts for this, for as fast as the heat comes the molecules of water receive it, and are as immediately replaced by others greedy for heat. If the heated molecules did not move, then the absorbing power of water would bear a different figure in the table.

As soon as the heat is felt, and absorbed by the water, Convection is set up, and the heated water is soon in swift movement through the pipes (see Chapter II., THE CIRCULATION OF WATER), and in a comparatively short time the heat is against the inside walls of the radiators or pipes, which are

fixed with a view to distribute the heat. Here the heat finds itself enclosed in a space composed of a material (iron) which allows of its readily reaching the outside by the action of Conduction. From the outside it is distributed, partly by Radiation but chiefly by Convection, in warming the air (see page 10).

Between the furnace and the radiators,* however, these actions can occur to the prejudice of the apparatus, and this should always have the careful consideration of the engineer. An ideal apparatus would be one in which the fullest possible proportion of the heat evolved from the fuel was delivered from the radiators or pipes in the rooms (or whatever place is being heated), and the engineer has to arrive at this ideal state as nearly as he can. It is loss of heat tha the has to guard against, for this means waste of fuel, less heat in the radiators, much slower results, and sometimes an inefficient circulation. The distributing pipes between the boiler and radiators, also the outer surface of the boiler itself, are all heat losers, and as they are nearer to the source of heat than the radiators, they are of a higher temperature and lose heat faster. These pipes and surfaces should always be covered (as described in a later chapter), and heat diffusion should be restricted to those places where the heat is wanted.

THE UNIT OF HEAT.

Although the majority of those practising heating work never make use of calculations into which the unit of heat enters, yet it is highly desirable that all should be acquainted with it and be ready to use it as required.

The British Thermal Unit, or B.T.U. as it is usually written, is the unit of heat employed in calculations in this country, and generally spoken of as the "heat unit." It is that amount of heat required to heat one pound of water one degree Fahrenheit. The degree is from 32° to 33°, and for

* In speaking of radiators it will be understood that any description of radiating appliance is meant, including coils, plain pipes, or whatever may be used.

very precise work this would have to be borne in mind; but for general purposes the unit is given the same working value at all temperatures.

The unit of heat, or B.T.U., which will heat a pound of water one degree will heat 52 cubic feet, or $4\frac{1}{8}$ lb., of air one degree also, and no engineer is long in discovering that air is more readily warmed than water. In fact, gases and most solids require less heat for a given rise in temperature than water (this being termed specific heat). With water as 1·000, iron is 0·130, copper 0·095, mercury 0·033 and lead 0·031 Even ice stands at 0·504, alcohol 0·622, petroleum 0·434.*

It follows that if one heat unit will raise a pound of water one degree, it will require fifty units to raise it fifty degrees, and so on. In the same way if a gallon of water, which weighs ten pounds, has to be raised in temperature one hundred degrees, then it will take a thousand units to do it; or perhaps it should be said that the water will have absorbed one thousand units in getting this heat.

It is estimated that high quality coal can yield 13,000 heat units per pound, while coke is given a heat value of 9000 to 10,000 units. As to what number of these units are absorbed by the water in a hot-water boiler, must rest with the boiler-maker, the pattern of the boiler, the draught in the chimney, and the person who attends to the fire; and it must be considered a liberal estimate if we say that three-fourths is utilised.

In regard to the number of heat units given off by heated surfaces, if a radiator is considered to be at full heat at 180°, and the air around it to be 60°, then the loss per square foot of surface per hour is 230 units. If a room has 1000 cubic feet of space (air) in it, and 1 unit will heat 52 feet of air 1°, it will require 20 units to heat the room 1°, or 560 units to heat it from 32° to 60°. According to this, $2\frac{1}{2}$ square feet of radiator surface would suffice to afford a 28° rise of temperature in this room, *but this it will not do.* If there were no change of air and no heat loss, this calculation might be correct, but under actual conditions this area of radiation must

* It should be stated that any substance taking a small amount of heat to raise its temperature has only a small amount to be given out in cooling.

be multiplied between five and six times. With a room having a normally effective chimney in it the air is changed several times per hour; then there is the loss of heat by glass (windows), and a trifling loss through the walls and ceiling. The area of glass influences results greatly, as will be found under the chapters entitled QUANTITIES. From a heating engineer's point of view, glass might be considered as a "necessary evil," as it is such an active heat loser.* It will be seen, in the chapters just referred to, that a lean-to conservatory, having a brick wall forming its highest side, and brickwork all around to about 30 inches high, requires about four times as much radiating surface (for a given size and given temperature) as a brick-built room, although the room may have a good sized window in it, and have a much more active air movement for ventilation.

The Calorie is a standard of heat measurement used in most Continental countries. It is the amount of heat required to heat 1 kilogramme of water 1° Centigrade, viz., from 15° to 16° C. The Calorie is equivalent to 3·9672 B.T.U., or practically 4 British Thermal Units. This unit of heat is always coupled with metrical measurements and quantities, and these are given in the APPENDIX at the end of the book.

The comparative thermometric scales of Fahrenheit, Centigrade and Réaumur are given in the APPENDIX at the end of this book.

* Extremely thick glass would not lose heat rapidly, but glass of great thickness does not come within the heating engineer's experience. Double windows, moderately well-fitting and with air space between, are not rapid heat losers, and, in calculations for heating surface, might be counted as wall surface only.

CHAPTER II.

THE CIRCULATION OF HEATED WATER IN PIPES, ETC.

THE actual cause of the circulatory movement that occurs with water when it is heated, is described in the previous chapter, under the heading of CONVECTION, on page 10. There the movement was shown confined to a single vessel; and when heating by hot water was first attempted, the circulation was also confined to single pipes. A boiler, much like an inverted large-sized basin, had a furnace beneath it, and from this boiler extended one or more sloping pipes, as in Fig. 6.

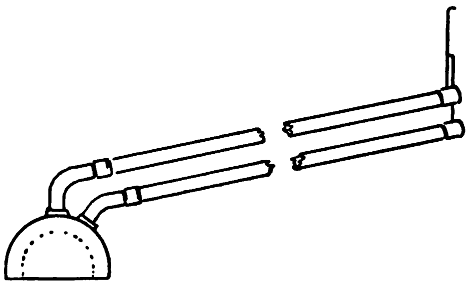


FIG. 6.

These pipes could not extend far, but would serve to heat a glasshouse of moderate size. It will be readily found that heated water will circulate in a single pipe from a boiler. If the pipe is vertical the circulation is quite free, up the centre and down the walls or sides of the pipe; if it is sloping (up from the boiler) the water ascends along the top and back along the bottom. About twenty degrees is the least slope, and then it requires to be a full-sized pipe. The single pipe circu-

lation, however, had a comparatively short existence, as it was soon found that two pipes could be used to greater advantage.

Nothing can give a better illustration of the circulatory movement of heated water in pipes than a few simple experiments with an apparatus of glass tubes, and it is strongly recommended that every student practise this. On page 11 was shown an extremely simple method of *seeing* the circulation of water heated in a vessel, and but little extra trouble is required to get a valuable experience of the movement in an apparatus of pipes.

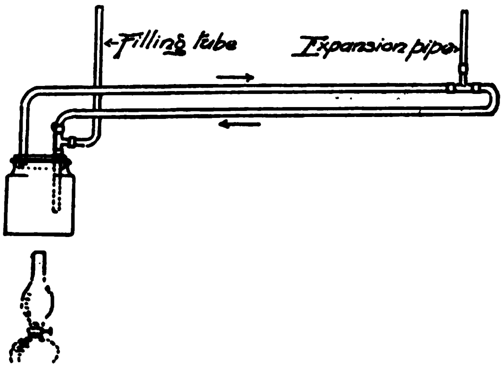


FIG. 7.

In Fig. 7 is shown such an experimental apparatus it its most simple form. A small glass jar, securely corked, a few feet of ⅜-in. or ½-in. glass tube (to be purchased at a halfpenny per foot), and the expenditure is nearly ended. The joints are made with short pieces of rubber tube, a size smaller and stretched on, while tee pieces can be formed of zinc or copper tube. The model is filled with water, in which has previously been shaken some amber or wood dust (see p. 11), and a lamp beneath will immediately start the circulation.

Of course such a simple arrangement as that just illustrated will do no more than show the action of the circulation out of and into the boiler, but the materials used admit of arranging the apparatus to suit anything that requires investigation. Not only is instruction to be gained, but many are the problems the writer has solved by this means. A student

or engineer, interested in this work, will find this simple model of glass tubes a source of much instruction and gain. The effects of dips in pipes, the causes of retarded circulation, the best (or otherwise) methods of branching, the peculiar actions of air in horizontal pipes (a highly important but neglected subject), and scores of other instructive things, are all made plain, and the reasons easily ascertained. One detail, little known, will be made very clear, this being that the circulatory movement commences practically everywhere at once. There is a common idea that after lighting the fire it must be confined to the boiler for a time, then to the nearest circulations, and so on. Instead of this, the instant a movement occurs in the boiler, there will be found an almost immediate movement everywhere.

In constructing this model, every detail of an ordinary hot-water apparatus must be included. The filling tube is equivalent to the cold-supply service, and a tin tank can be put at the top of this if desired. The expansion pipe must also be put to allow for air escaping, particularly when charging or filling with water. It must be admitted, though, that considerable instruction can be obtained by omitting or temporarily stopping either of these pipes—or trying to make one serve both purposes—for more can be learned from a faulty detail than from a perfectly working apparatus.

One peculiar result that can be obtained with this model is that of a regular circulation occurring when the pipes in the jar or boiler neither project down inside and are quite level at top. It might be thought that no circulation would occur, but instead of this the movement commences as quickly, and continues to flow as freely, as if the pipes were one high and one low, as customary. The different heights at which the pipes join a boiler, or terminate in it, are quite unnecessary so far as obtaining a circulation is concerned, but with the ends level there is no certainty as to which pipe will constitute itself the flow pipe and which the return. It is, therefore, a proper practice to connect the flow pipe at the extreme top of the boiler, and the return at the bottom or near the bottom. The pipes can then be described by their respective names

before the apparatus is tested, as there is a certainty of the highest pipe acting as the flow and the lower one as the return. With level pipes there would be a decided uncertainty, and, strange to say, the writer has found that at separate tests one pipe will act as the flow on one occasion and be the return at another time.

It will be seen from the description given as to the cause of the circulatory movement of heated water, on pp. 11–13, that the action must be strongest when the water has to travel straight up and down; and the height of the two columns of water must also govern results. Another and perhaps the chief factor in varying the speed of the circulation is the amount of heat lost by the water. The greater the difference of temperature of the water in the flow and return pipes, the greater must be the weight of the two columns—for temperature is equivalent to weight in this respect; but it is only in vertical height that this counts, as the water in horizontal pipes does nothing to cause a movement. Therefore a high apparatus, consisting chiefly of vertical pipes, must have the strongest circulatory movement, provided it is constructed in a correct manner.

It is seldom, however, that an apparatus, even when high, does not have a considerable amount of pipe running in horizontal directions; but, happily, water is so ready to move and circulate when it receives heat, that the amount of vertical pipe may be quite small compared to that running in other directions, and yet make a perfect working apparatus. By referring to Chapter VIII., in which hot-water works devoted to horticultural buildings are described, it will be found that an apparatus may consist of hundreds of feet of pipe, yet the total amount of vertical pipe in it may be no more than six to ten feet. Such an apparatus will work well in all respects and give no trouble. All pipes in such an apparatus (and all others) are given a gentle rise from the boiler to their most distant points, but this is to facilitate the escape and discharge of air more than anything.*

* The subject of Air in Pipes will be found treated fully in a later chapter. It is a subject of considerable importance.

The engineer has to use judgment, and exercise his best skill, when an apparatus has to consist partly of vertical and partly of horizontal pipes. Most works are of this kind, but this fact does not make the difficulty any less. It is not a trouble when the upright and horizontal pipes are merely a continuation of one another. It is when the pipes are branched, as they have to be. Take Fig. 8 as an example. This shows a vertical branch from horizontal mains, and, without the aid of stop-valves, it would be difficult to get a good circulation through the horizontal work which is beyond this branch. The vertical circulation will be much the stronger, and this tends to decrease and retard what would otherwise be a

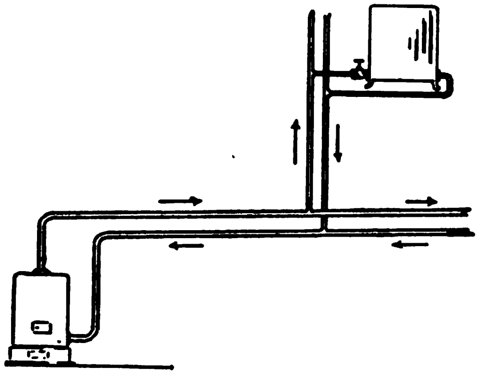


FIG. 8.

normal circulation along the distant horizontal piece. This is one of the instances in which the difference in strength of circulation must be considered; it is not that the horizontal part of the work would not ordinarily have sufficient movement, but that branches may interfere with it. In the instance just given the vertical flow could be checked by using a small pipe for part of it, or inserting a stop-valve (which should have a key that can be removed when the valve is set); but the better plan would be to commence this branch horizontally for a few feet, or by running a distinct circulation from the boiler, if it should be at all near; or there will be found other ways of overcoming the difficulty, according to the conditions.

One of the best plans that can be adopted in hot-water heating works is to get separate circulations from the boiler, rather than branches from a pair of main pipes, where this is possible. More uniform results are obtained in this way, and, considering that uniform working in all parts of a hot-water apparatus (when it extends in different directions and to different heights) is most difficult to get, every reasonable means should be adopted to this end. Whether there are separate circulations or branch circulations, it is necessary to

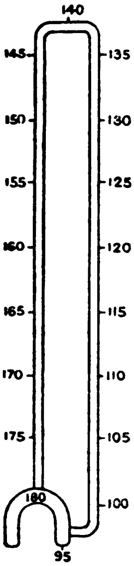


FIG. 9.

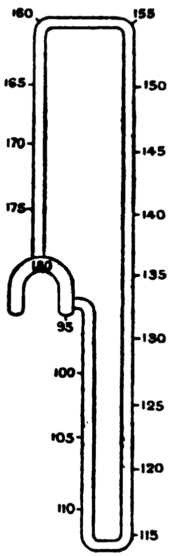


FIG. 10.

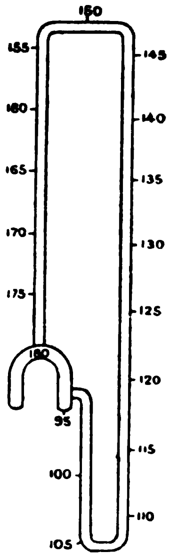


FIG. 11.

have stop-valves to control the circulation through those circuits which are either short or have much vertical pipe, or possess some details which favour them ; for what is to their advantage is nearly always at the expense of the harder working circuits.

In Box's standard work on "Heat," a very simple method is adopted of showing what constitutes the motive power in a hot-water apparatus, sketches being given something like Figs. 9 and 10. In these, regular spaces are marked off, it being supposed that the water in travelling loses five degrees

of heat between each point. What amount of heat it might lose is never known in practice, for it must vary with every job, and the pipes of each job must lose heat more in some rooms or situations than others. But they all lose some heat, and the instruction contained in the diagrams remains sound. In Fig. 9 there is a mean temperature of 160° in the flow pipe, with 117° in the return, a difference of 45° to furnish the motive power. This 45° represents a distinct weight or pres-

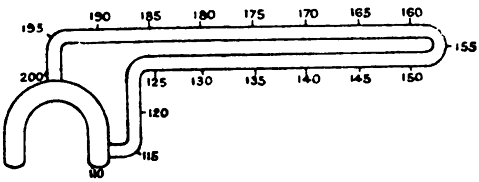


FIG. 12.

sure, and with a vertical circulation as shown the movement would be very rapid. In Fig. 10 the mean temperature is 135° in both columns, so that theoretically there would be no movement. In practice, as may be ascertained by a model, as suggested at the begining of this chapter, there will be a movement, but it cannot be counted on as a useful one for practical purposes.

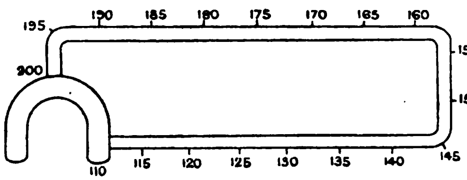


FIG. 13.

What Fig. 10 shows us is that a dip in the circulation, even to some part of it extending below the boiler, is possible. Take Fig. 11, for example; a model erected to this pattern will quickly show a positive and good circulation.

Another instructive illustration may be given in Figs. 12 and 13. The first shows what may be termed the typical method of connecting up a horticultural apparatus of cast pipes, and it will be seen that, in adopting this plan, the greatest

difference of temperature is obtained in the two pieces of vertical pipe, where the motive power of the circulation may be said to exist. In the second figure the difference is less, owing to the vertical piece of the return being at a point where the return water could not ordinarily be at its coolest temperature. This last illustration does not show an impossible apparatus, as occasionally in some works the upper or flow pipe of an apparatus has to be carried along a ceiling, then descend and return along the floor. The purpose of the illustrations, however, is to make clear how the circulation can be improved or favoured—or otherwise—under certain conditions.

With either of the examples just given the circulation would be strong enough to be considered quite satisfactory, although the small proportion of vertical pipe to that which is horizontal is very marked. Such horizontal works usually

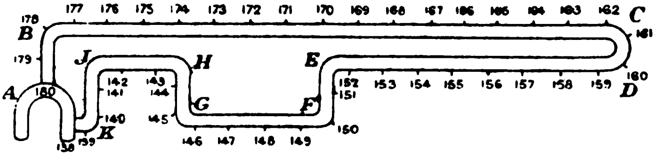


FIG. 14.

appear in horticultural buildings, and in these the pipes are always of large size, 3 in. or 4 in., and this detail assists good results materially by reducing the element of friction. There now, however, arises a more difficult point to be settled, this being the possibility or otherwise of introducing dips into circulations. It was shown at Fig. 11 that a considerable dip was possible, provided the loop or circulation above the boiler was sufficient, but in works consisting almost wholly of horizontal pipes this will not apply.

Let Fig. 14 serve to explain this. From A to B there is a mean temperature of 179°, while from J to K the mean is 141°, a difference of 38° in favour of the circulation. At the dip the two upright pieces of pipe are in favour of a retrograde circulation, the falling column E to F being lighter than the ascending column G H. These spaced off show a difference of 7°, which is opposed to the normal direction of the circula-

tion, and which must be deducted from the 38° last mentioned. This, however, leaves ample margin for satisfactory results, and such a dip can be put in successfully. Of course if the space between F and G should be much increased, there must be greater resistance caused; and, in the same way, if the space anywhere from F to H was subjected to a greater cooling influence, the normal circulation must be prejudiced.

In Fig. 15 a further and final example is given, this showing a dip below the boiler. It will be seen that the apparatus presents no unusual features from A to the point marked with an asterisk, and only the dip below this level has to be considered. A glance at the figures will show that this dip, in an apparatus as shown, is permissible.*

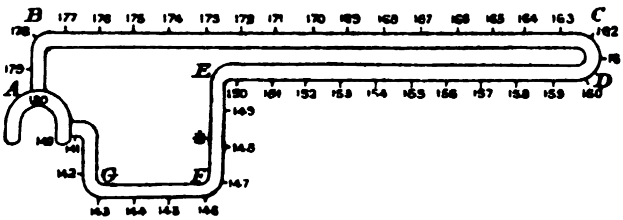


FIG. 15.

With horticultural works (and occasionally in other instances) a simple plan can be adopted to overcome the resistance of a dip—or of a length of circulating pipe which has to run at a low level—this plan being to introduce a small cistern or tank, as Fig. 16. This needs no explanation beyond saying that the cistern is put as high as it can reasonably be got, for the higher it is the more successful it must be in overcoming the retrograde force that exists in the low section of piping. The cistern can be fed by hand—as is usual with horticultural works—or it may have a small supply cistern, with ball-valve, at its side.

As previously stated, a good circulation can be obtained if the pipes both start level from the top of the boiler, but there

* It is of the highest importance, when dipping a circulation, that the effects of air in the pipes have the fullest consideration. This will be found clearly explained in the chapter dealing with this subject.

will be no certainty as to which pipe will act as the flow and which the return ; and the reason, therefore, for connecting the intended flow pipe high and the return low is to ensure, when the apparatus is used, that both pipes shall act up to the work assigned them.*

As to the distance the flow and return connections at the boiler should be apart, Hood in his earlier works considered that 12 inches should be considered the minimum. This distance can be readily got on most boilers, but it will be found that a much less distance will serve quite well should it be desirable or necessary. It is certainly preferable to have the distance as great as possible, for, with the majority of boilers,

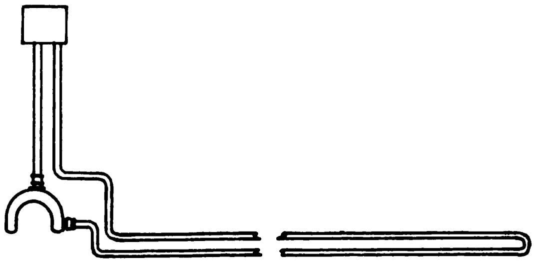


FIG. 16.

to reduce the distance would mean making the return connection high up, and there is no gain, either in effect or cost, in this.

The flow connection is, or should be, always at the extreme highest point of the boiler, while the return joins the side or back of the boiler at as low a point as can be conveniently arranged. This is usually within 3 inches of the bottom of the water-way, or that part of the boiler which has water in it.

* There is nothing to be gained by connecting both pipes level at the top of the boiler. If there was, then the direction of the circulation could be ensured by two means. One would be to arrange that the greatest amount of pipe and radiating surface be on the return pipe or pipes ; or, should the work be about equally divided between flow and return, then by arranging that the greatest heat be felt below the flow connection. This can be easily tried with the model suggested on page 21 ; but, except as a study of the subject, it conveys no instruction, as boiler connections can be so readily made high and low in the usual way.

An exception to this rule occurs in what is now usually termed the "Loughborough" type of boiler. This is described in the Chapter on BOILERS, and will be found to consist of a boiler which can be fixed in a greenhouse wall, with its back part projecting inside the greenhouse, the pipes being there connected and run horizontally* as required. To allow of the pipes running one close beneath the other, the connections at the boiler have not a greater distance than about 4 inches between them, yet, although the pipes run horizontally (with the usual slight rise from the boiler), and at no point is the flow or highest pipe more than about six inches above the boiler, the circulation is quite effective. The writer has, too, in other works, obtained a good circulation through some hundreds of feet of small pipe (in which friction offers much resistance compared to large pipes) with only 3 to 4 inches vertical distance between the flow and return connections at the heater. The fact that a circulation occurs in two pipes starting level, and being apparently alike in all respects, shows plainly that some trifling inequality, not noticeable to the eye, will bring about the circulatory movement up one pipe and down the other. The recommendation still remains, however, that the flow and return be, the former at the top, the latter near the bottom of the boiler whenever possible.

If the foregoing particulars appear to refer more to glass-house than-other works, it is only because this kind of apparatus lends itself best to the discussion of the subject, and it will be found in the later pages that works suited for all conditions and purposes are treated about equally.

* It should be noted that when speaking of horizontal pipes in this work, it means pipes run in a horizontal direction with more or less rise or fall to them. Hot water circulating pipes should never be run quite horizontally, as, apart from whether this would prejudice the circulation, it would not allow air to get away. The least rise or fall is 1 inch in 10 feet. See the subject of AIR IN PIPES.

CHAPTER III.

THE ADVANTAGES OF WARMING BUILDINGS BY HOT WATER.

THIS short chapter includes no practical instruction in hot-water work, but is introduced with a view to describing clearly and without exaggeration—or prejudice—what advantages are to be gained by this mode of heating. Every hot-water heating engineer has to argue in favour of his speciality occasionally; in fact, often, and not infrequently, he has to overcome strong prejudice. It is rather remarkable how much prejudice exists, but in practically every case it proves to be associated with complete ignorance and inexperience. The most prejudiced person is nearly always the one that has never been in a house or place properly warmed by hot water. It must be unhealthy, they say, stuffy, unbearable; they consider the sight of a fire something they cannot do without—and so on. This latter argument is easily overcome by asking if the sight of a fire is welcome and cheering on a summer day, and it is admitted that it is not. A house properly warmed by hot water has perpetual summer in it; not the heat and glare of mid-day, but the temperature and atmosphere of the evening, the time when the sun is not visible and everything is so particularly agreeable.

The writer may explain that for several years he has lived only in houses warmed by hot water, the work being superintended by himself, and although a technical treatise is not supposed to deal with domestic matters, yet in the warming of residences the lady of the house must influence things. In the writer's own case, on first introducing the heating apparatus,

there was the customary doubt (amounting to strong prejudice, as it usually does), and dissatisfaction was anticipated. It is necessary to mention this to show what a complete change of opinion came with subsequent experience. It was afterwards admitted that no idea had been formed or imagined as to what agreeable results the apparatus would afford; and, briefly, a distinctly prejudiced woman was converted, without argument or persuasion, into a really enthusiastic votary of this mode of heating.

In a recent instance there were 13 radiators, heating approximately 30,000 cubic feet of space. The fire was kept alight night and day, and the consumption of ordinary gas coke was slightly over 1 ton per month in the coldest weather, and slightly under at other times, or say about 7 tons per winter season (extending from about October 1 to April 30, or a little longer). This is a very economical outlay to warm 9 full-sized rooms and a hall and corridor, for 24 hours every day.* The boiler was of sufficient size to take a charge of fuel that would last through a night of 9 hours, and although the temperature would fall at night (as it does in summer, and as it is desirable for it to do), no need for any change in the summer bed-clothing was experienced.

In addition to the economy in fuel, there is a pronounced economy in labour. The attention to the *one* fire may be four times daily, this attendance being of a very brief duration. Each morning there is no stove cleaning, nor fire lighting, nor the dust and dirt that accompanies this. Should it be a country house, set well back from a road, the dust trouble almost disappears.

Perhaps the greatest advantage is that of uniform temperature. In the writer's case it is believed a record has been established—a household of eight (all ages) passing two successive winters without a single cough or cold. No care is needed in this respect, no anxiety with children as to draughts and the like. It was the regular practice for two young

* It is probable that to get the same resulting warmth in these rooms, for the period named, at least three times as much fuel would be required if fires in open grates were the source of heat.

children to walk in their night-dresses from a bedroom along a corridor to a bath room, at 7.30 a.m. each day; and whatever the weather might be outside it made no difference, for winter was the same as summer as regards warmth and salubrity of atmosphere. It may sound a trifling detail to some, though it is not to the housewife, that servants find less difficulty in staying in a house well and efficiently warmed by hot water. A house has to be kept clean, and to effect this there is a room being "turned out" almost every day. It is difficult to imagine a more miserable task than this on a really cold day (in the average house); but in a warmed house it is, as just stated, the same in winter as in summer—perhaps more agreeable, for the full heat of summer is not always agreeable. It takes a woman, however, to give a proper value to the benefits that an agreeable warmth afford when house-cleaning, or housework of any kind, is being done in the winter.

One agreeable detail soon noticed in a house properly warmed by hot water, is that there are no draughts. A draught may be correctly defined as a current or movement of air that is cold enough to produce a disagreeable sensation to the body, or, it might be said, is cold enough to be perceived. Currents of warm air are not perceivable, and the ideal warmed house that is being described appears to have a soft, still atmosphere, such as is experienced on a few summer evenings. The air appears to be more silent (if it may be so described), which would perhaps be due to its conveying sound waves less sharply. It could easily be thought that the air was still, and the ventilation (change of air) insufficient for healthful results, but any simple test will show that the air movement is as active as in a house heated by fire-grates with its consequent cold draughts. This is assuming that there are chimneys in the house, or their equivalent, to act as extractors of vitiated air. These exist in practically every house; but should a house be newly built, and the heating is to be done by hot water, without any provision for fires, then air flues must be provided in the walls, and these will act as extractors as chimneys do.

It is about the only thing that can be said in favour of the fire-grate, that its chimney provides an automatic air-extractor to cause the air of the room to be changed, but, as stated, it induces cold draughts if the grate fire is the only source of heat. Many houses are fitted with a hot-water apparatus as an auxiliary to the warmth afforded by fire-grates. It is a good plan so far (though the writer finds the grate fire positively unnecessary, and affording no pleasure to those who otherwise favour the visible fire), and those who insist on seeing a fire can thus have large rooms properly warmed, also their halls and corridors, while preserving the cheerful effect that an open fire is thought to afford.* In such cases as these the area of radiation is reduced one-fourth, and this (without the fires) will be found to afford a nice temperature when the outer air is above say 37° Fahr., the fires not being required until there is a sensation akin to frost in the air.

Another point in favour of hot-water warmth relates to the question of dampness in houses. Anyone who has lived in a country house (however dry the district may be considered to be) will be perfectly familiar with this subject; and as so many of the heating engineer's works are in rural districts the subject is, so far, important. Town dwellers have no idea how damp a really good and well built country house is, even when built in a situation that is favorable as to dryness and a bracing air. There are no objections whatever to the humidity of the air from a healthful or hygienic point of view, but as leather shoes and boots have a vigorous growth of blue mould on them in a week, and even dresses hung in a wardrobe become mouldy in a brief time, the subject assumes considerable importance in the housekeeper's eyes. Spare bedrooms, too, are a source of anxiety. Hot-water heat—meaning a fairly uniform summer temperature day and night through the winter—will remedy this as far as possible, and reduce the trouble to reasonable bounds. It may not prevent it entirely, for it is not a thing that can be wholly prevented by any ordinary means—and perhaps it is

* There is no desire to condemn the open fire, but in a house well warmed by hot water the visible fire is scarcely agreeable, and is never sought for.

as well that it should be so—but it reduces a real source of trouble and anxiety to one only needing ordinary care or thought.

As to the gain effected in a household, generally, this, though made up of many details, represents a large total. The inconveniences of winter, in an ordinary residence, are many and varied. This everyone knows, and needless to say the whole are due to the want of warmth and salubrity that the summer air has. A person's nature and feelings, their ability and inclination to work, the quality of their work, and a score of things, are distinctly influenced by their comfort, and this latter word is practically equivalent to the term "that things go smoothly."

As to health, let it most clearly and emphatically be stated—and it is beyond dispute by any experienced person—that the health is benefited. It is not that the health is not prejudiced; it is more than this, for a real benefit is had, both to young and old. Appetites are as keen as could be wished, there is no lassitude nor anything that is associated with high temperatures. As already stated, the temperature, the atmosphere, and the general effect is that experienced on a summer evening, when the temperature has dropped to 60° to 65°, a temperature that is found to stimulate the mind, the body, and the appetite.

A question is often raised as to whether a cold is not the usual result of walking from a house at 65° into the winter air. The writer can answer this beyond dispute by saying it never is so. In the first place no one goes out without clothing themselves suitably, but, apart from this, what does nature inspire us to do. The average person thoroughly warms him or herself by the fire before they go out, or they take a warm meal or beverage, and everything points to the body requiring to be warm—as warm as possible and warmed through—before going into the cold air. Only under stress of circumstances does anyone go into the cold air while they themselves are in a cold condition. A previous statement in this chapter, too, disproves the "cold-catching" idea, for a household of eight, of all ages, passed two whole consecutive

winters in such a house without once catching cold ; and, needless to say, all went into the outer air one or more times every day. It should perhaps be added that the members of this household were not particularly vigorous either physically or constitutionally, two were rather the reverse but showed great and permanent improvement very soon. The winter is a trying time with many people, of all ages, but only because they live in houses the atmosphere of which is inclement and distressing to the human body.

'CHAPTER IV.

THE DETAILS OF A HOT-WATER HEATING APPARATUS FULLY EXPLAINED.

BEFORE giving illustrations and particulars of example works (which form the subject of the next chapter), it is thought best to describe the detailed parts of an apparatus so as to make the reader familiar with the reasons for their existence, their uses, etc. This can be done by describing a small and simple apparatus, and it will be found that the general information afforded will apply generally to works of all sizes and on all "systems." A further use for this chapter is that it will make the examples in the next ones (Chapters V., VI., VII., VIII.) readily understood without tiresome description and repetition in each case.

It is assumed that the action of convection—the circulation—is understood from the description given in Chapter II., and that the general results to be expected when erecting a heating system are understood; if not, then the description afforded in Chapter II. must be referred to. For the purposes of this present chapter, therefore, Figs. 17 and 18 are given, these representing a simple apparatus on what is known as the "two-pipe" system.*

It is supposed that a dining-room and a drawing-room of a residence—both large rooms—require some warmth, as the fireplaces are not large enough when the outdoor temperature is at or below freezing point. This quite frequently happens, for the fire in a fire-grate of the best and most modern make

* The different systems are described in Chapters V., VI., VII.

is seldom quite sufficient when a room exceeds 20 ft. by 18 ft. In the case of a drawing-room it is often required, when the help of hot water warmth is decided on, that this be fully heated without the aid of a fire, as the room is thus kept cleaner and is ready for use of visitors at any time without the servants having to run in and out.

In Fig. 17 there are three radiators, one in the dining-room as an auxiliary to the fire-grate, and two in the drawing-room; and it is supposed that the boiler is in a scullery or kitchen

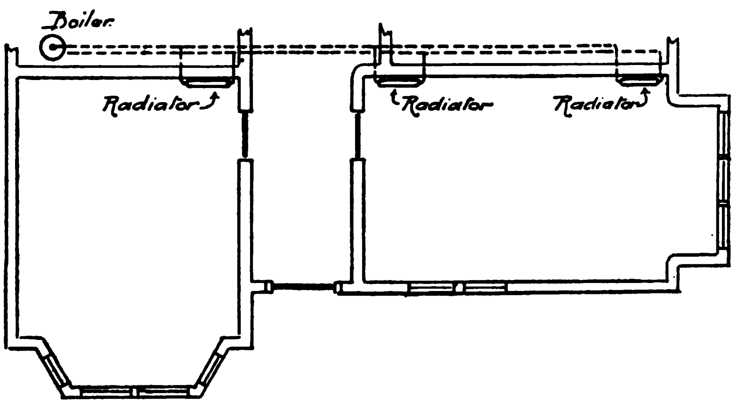


FIG. 17.

office in the basement, while the pipes run along beneath the basement ceiling.*

From the highest position in the boiler † the *flow pipe* proceeds by the most direct or convenient route to the point where

* The sketches are made to form a simple example, otherwise it would have been desirable, while doing the work, to put a radiator in the entrance-hall; where, as is usually the case, nearly all the cold air first enters the house. It will be found mentioned more fully in later chapters, but may be stated here, that in many residences a full degree of warmth in the front and back halls amounts to nearly half the efficient heating of the house.

† Fig. 18 shows the flow-pipe leaving the side of the boiler close to the top. It is probable, in a small job like this, that an inexpensive boiler of this make would be used; but where possible, boilers should always have the water way extend over the top or crown (see BOILERS) in which case the flow always leaves the extreme top of the boiler by a vertical pipe.

the radiators are to be situated,* and it will be seen that the *return pipe* takes the same course, but it joins the boiler near the bottom. It is important that both pipes are given a rise or slightly ascending course (where they run in a horizontal direction) from the boiler, and the least rise allowed is 1 inch in 10 feet. This should always be exceeded if possible, though it is not necessary to give a greater rise than, say, 4 in. in 10 ft. if it makes the run of pipes unsightly on the wall. The chief purpose of this rise to the pipes is to allow of air being expelled (or getting away by itself) freely. Air in the pipes is a source of real trouble to the heating engineer until he is conversant with what it can and does do, and on no

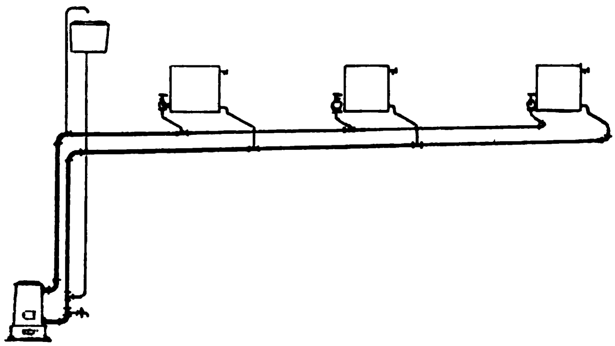


FIG. 18.

account must a student ever consider it a detail of minor importance. It is air that usually makes all the difficulty when a flow or return pipe has to be dipped or made to descend (lose its rise) in any way. The strength of the circulation may be fully powerful to allow of the dip, and when done it may be quite successful, but success will lie chiefly with the skill displayed in disposing of the air that has to be displaced or given freedom of escape. (See AIR IN PIPES.)

The flow pipe proceeds from the highest point of the boiler (so that no air-chamber may be formed at the top of

* Should cast pipes ever be used instead of radiators, as in a conservatory attached to a residence, the general work and connections remain the same. The way in which cast pipes are joined up will be seen in the chapter on HORTICULTURAL WORK.

the boiler), and then proceeds along past near the positions given to the radiators, and, with this system, it may join and end in the last radiator as shown. The return follows the same route, either by the side of the flow or beneath it; it might be carried above the flow if desired, but in the trade the lower pipe of any pair is usually considered the return.

The radiators (or coils, or other heat-distributing devices) are connected by branches to the flow and return as shown. It is not a good plan to let the main pipes come directly beneath the radiators, so that the branches are merely short pieces of vertical pipe. It is better to keep them from one to three feet away; for, although this entails more labour and using at least two more bends, it allows of the pipes expanding and contracting (as they heat and cool) without straining the joints. Perhaps this may not be of such importance in a small apparatus as Fig. 18, but it is the rule, and it is very necessary in large works where the push and pull of the main pipes, when heating and cooling, must be allowed for. Joints may be strained, leaks started, and injury done to cement and decorative work. In long straight runs of pipe special provision for expansion has to be made, apart from the branches, but this detail is treated separately. (See EXPANSION JOINTS.) The same rise is given to branch pipes and connections, as is given to main circulations, viz., 1 inch in 10 feet as the least; double this, or more, when possible.

The reason that the last radiator may have the main circulation end in it (as shown in Fig. 18) is that each of the other radiators forms a by-pass between the main flow and return. Thus, if the stop-valve on the end radiator was closed, and the circulation through it quite stopped, it would not interfere with the circulation through and the proper working of the others. It may be thought that the end radiator should be connected as Fig. 19, so as not to stop the main circulation past it, but there is no gain in doing this with an end radiator when on a two-pipe system of apparatus. With the one-pipe system, which is described in Chapter VI., the argument applies differently, as the radiators nearer the boiler

have no connection with the return pipe, and any valve regulation affecting the main circulation at its extremity would affect all and be a fault.

It is a fault laid to the door of the two-pipe system, that, as every radiator, and every branch circulation, is more or less a by-pass between the main flow and return pipes, it favours what is termed "short circuit." This means the possibility of the circulation occurring up to and through a certain branch, and returning from there without moving the water in whatever part of the apparatus extends beyond that point. Take Fig. 18 for example (though as a rule the trouble only occurs with much larger and complicated works). In this let it be supposed that the circulation occurs normally through the first and second radiators, while the third one remains cold and apparently has not warm water working through it. This would be considered as a case of short circuit. The "one-pipe" system which is described in Chapter VI., cannot have this trouble, but the fact is that all systems give trouble if they are not properly carried out, and short circuit is only an instance of this. Its chief cause is want of boiler power, or using pipes of too small a size. It might be supposed that with either of these mistakes the result would be a general failure, but it is not so; and the rule is, in such cases, for part of the apparatus to work fairly well and part to fail entirely. This peculiar result is always puzzling until it is understood, for the part that fails sometimes acts as if it was quite cut off from the rest by a stoppage of some kind; and until the fault is remedied it is a dead part of the apparatus.

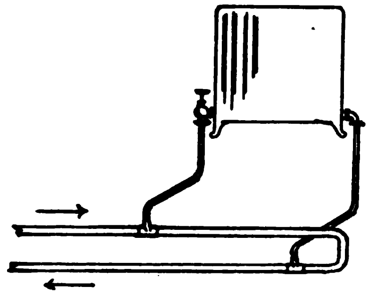


FIG. 19.

Short circuit, stated briefly, means faulty construction, boiler or pipes under size. There may be exceptions, as in the case of badly dipped pipes, or pipes that get air locked,

but these are not so permanent or regular in their failure, and can usually be distinguished both by their action and by inspection.

Referring again to the description of the apparatus illustrated by Figs. 17 and 18, a detail of some importance is the "expansion pipe." This often bears other names, such as "steam pipe," "vent pipe," etc., but the first is the correct name, as can be shown. The pipe would certainly allow of steam escaping should the water boil, and would do good service in this respect, and it also allows of air being expelled. The customary point at which it exists is on the highest point of the circulation, but in Fig. 18 it is shown nearer to the boiler, to allow of discussion, and to show that the highest point, though considered best, is not essential.

When the expansion pipe is at the highest point it allows of air passing out freely, either at the time of charging the pipes with water, or afterwards.* If it is not convenient to put the expansion pipe there, then it may be placed anywhere on the flow pipe, *provided* some other means exist for the air to get out of the circulating pipes. In the illustration referred to it will be seen that a radiator exists at the highest point, and this will take the air satisfactorily. When charging the apparatus with water the radiator valves are (or should be) open, therefore the air at the highest point is disposed of quite perfectly. Afterwards, when the apparatus is in normal use, the air that works to the highest point will collect in the radiator; and all radiators are made so that they will take a reasonable volume of air at the top without interfering with their work or heating. In an apparatus like that now being discussed (Fig. 18), the air-cock on the radiator on the highest point might not require to be opened more than twice, or three times, during the whole winter season.

As, therefore, the expansion pipe is not of primary importance in giving free vent to the air in an apparatus, and

* Air is always collecting in a hot water apparatus, not in great quantity but sufficient to cause trouble if provision for its free exit is not made. This is one excellent reason for giving the circulating pipes the rise stipulated.

may never be called upon to act as a steam pipe,* the question may arise, what is it for? It is to provide for expansion! Water, when heated, expands in a regular manner, and it might be thought that this could be provided for in the size of the cold supply cistern. As a matter of fact this is done, *and has to be done, in every case* (see SUPPLY CISTERNS, sizes of) yet this provision does not obviate the necessity of the expansion pipe. Let an experience of the writer's confirm this (and nearly every engineer has had the experience). An apparatus of moderate size, with eight radiators, was erected in quite an ordinary manner, but it was not easy to get an expansion pipe in. It was omitted, and, as usual, the cold supply cistern was made of full size, and had only about 3 inches of water in it when the apparatus was cold. Soon after lighting the fire, and before the radiators were really hot it was noticed that the water in the supply cistern was rising at quite a rapid rate. In a very brief time it overflowed, although it was fully large for the mere expansion of the water. On testing again it was found that the water appeared to swell back in an unaccountable way, and no care in stoking or attention to other parts of the apparatus would prevent it. The provision of a $\frac{3}{4}$-inch expansion pipe proved to be a perfect remedy for this; and the writer has to acknowledge, with regret, that he cannot, nor has he found anyone who can, give a very clear reason for this phenomenon, which is now known as the "swelling back" of water in a supply cistern.

A further detail of the apparatus, Fig. 18, to be explained is the cold supply service. This is an important pipe, and must be correct in connection and detail. In the first place the supply cistern must be of suitable size. As already explained, water when heated expands, that is increases in bulk, to a recognised extent, and this being so, some provision for the increased bulk must exist in every heating apparatus. Failing this provision, there would probably be an overflow and other troublesome happenings. Water heated from its

* Supposing no expansion pipe existed, and the water boiled, the steam pressure could relieve itself by way of the cold supply pipe. Apart from this, every boiler, without exception, should have a safety valve on it.

point of greatest density (which is near freezing) to boiling point, expands one twenty-fourth—that is, 25 gallons of water just on boiling point would be but 24 gallons at near freezing point, and the weight of the two would be the same.

In heating works a provision for expansion of 1 in 24 is not usually made, yet when starting an apparatus in winter, with a good boiler, there may be a rise in the temperature of the water of very nearly 170°, so that 1 in 24 is scarcely too much to allow. This means that the supply cistern, which has about 3 inches of water in it when the apparatus is charged cold, must have sufficient space above (below the overflow pipe) to take quite 1 gallon for every 20 to 24 gallons of water that is in the boiler, pipes, and other parts of the apparatus which the cistern supplies. Supposing the cistern to be fitted with a ball-valve, then this comes near the bottom of the cistern, and when the apparatus is cold it appears as Fig. 20. The dotted line near the top shows where the water may rise to when the apparatus is at its fullest heat, this line being just below the overflow pipe.

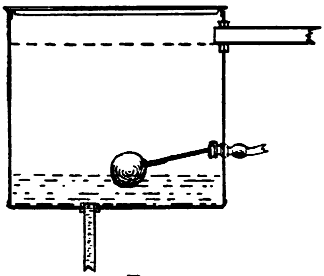


FIG. 20.

In the APPENDIX will be found a table that gives the quantities of water that pipes of different sizes hold per foot-run, and in regard to radiators it may be taken that their water capacity averages about $\frac{1}{5}$th gallon per square foot of surface. It is rather a bothersome calculation, and it is probable that the majority of engineers guess the sizes of the cisterns, allowing a margin to the good, as the low cost of cisterns readily allows them to do.

The ball-valve is not favoured as a means of automatically supplying these cisterns, chiefly because it is likely to become stuck through want of use, this result being made more certain by the valve being submerged—covered with water—when the apparatus is heated. It must be admitted, however, that nothing better is known if an automatic supply is required,

but if the conditions will admit, then a cistern without valve, and fed by hand, should be used. As a rule, there is little objection to this, as it may not require to be replenished more than once a month, and should it be forgotten there is no danger to be feared.

The plan that usually works out best of all is to take the cold supply service directly, or indirectly, from the house cistern. This is supposing there is a house cistern, and that taking the supply from this will not involve any special extra expense. It may be assumed that the house cistern is too large to have any appreciable rise in its water level due to the expansion of the water in the heating apparatus, and it is needless to add that this cistern provides a constant automatic supply to the boiler. It is not always necessary to take the cold supply service, as a separate pipe, all the way down from the house cistern. There probably is a domestic or other cold service already down to a point near to the boiler, and a branch may be taken from this. It may be argued that this is a doubtful practice, owing to the likelihood of the service being shut off for repairs, which would deprive the boiler of its supply, and the reply is that this does not matter, as a heating apparatus, as ordinarily constructed, will usually work quite well for several days with the cold water supply cut off, and at the worst there could be no danger and little or no inconvenience. The cold service down to a w.c. flushing cistern could be utilised quite well if of suitable size.

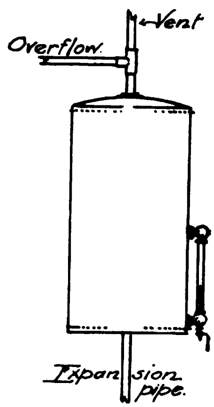


FIG. 21.

A peculiar form of supply cistern that has been introduced from America is known as the Expansion Tank. This is merely a galvanized wrought-iron cylindrical tank, with a water-gauge on it, as Fig. 21, about ten different sizes being made to suit apparatus from small to large undertakings. With this, as with other methods employed, the cold supply

pipe to the apparatus is carried into the boiler, or into a return pipe near the boiler, the object being to feed into the boiler as direct as possible, this being the only certain means of avoiding trouble from air collection when the apparatus is filled. (This will be spoken of again.) The cold supply pipe, however, is not taken from this tank, but is usually a branch from a main or other convenient service nearest to the boiler. The expansion tank therefore answers well where no house cistern exists, and may often be used instead of putting in a hand-fed supply cistern. If a house cistern should exist, however, it is best to utilise it, for it will probably save expense, and, more important, it will feed the apparatus automatically without giving trouble.

Assuming the expansion tank to be connected to an expansion pipe at the highest point of an apparatus, the water supply is then turned on; and, after it has filled the boiler, pipes and radiators, it will mount up and appear in the water gauge of the expansion tank. When it is about 3 inches up the supply must be stopped, and the fire can then be lighted. As the water heats so the water-line in the gauge attached to the expansion tank will rise, and from this time it will only be necessary to glance at the water-gauge to see if replenishment is necessary. The addition of water, as will be understood, is effected by opening the stopcock in the cold supply down by the boiler.

A little difficulty arises in the detail just explained in the fact that whoever opens the cock in the cold supply cannot watch the water gauge at the same time, and in consequence of this a second cold water connection is sometimes made, this one being to the expansion tank itself. It will be seen that once the apparatus is full, and all air lifted out of it by the water rising from below, there is no objection to the regular replenishment being effected at the top. Therefore a cold connection to the expansion tank will readily supply the little water needed periodically, and when doing this the attendant has the water gauge in sight to regulate the replenishment correctly.

As previously stated, the cold service pipe is connected

either direct into the boiler or into a return pipe quite near to the boiler, i.e. as near as possible, say, about within about 4 ft. This applies whether the pipe comes down direct from a feed cistern, or whether it comes as a branch from a domestic water service (see p. 45), and the object to be attained is a direct feed to the lowest part of the apparatus. In the few instances in which a return pipe runs below the bottom of the boiler, then it is a good plan, the best plan in fact, to feed into this return pipe instead of into the boiler. It is of considerable importance in the filling of an apparatus that the water enter at the lowest possible point, and rise from there. This ensures the most perfect possible expulsion of air. Previous to an apparatus being filled, or charged as it is called, it is, of course, full of air, and if this air is not all driven out by the water as it flows in, then there will be ill results occur afterwards. With a very simple apparatus it might be possible to fill by a cold service connected to a high part of the return pipe, quite away from the boiler, but it needs mature judgment to say when this can be done, and then it is only possible occasionally. The rule is to connect the cold service to the lowest point of the apparatus, so that the inflowing water *lifts all air above it* as it rises. With many works having branch circulations, and other complicated, so to speak, details, to connect the cold water at a point far from the boiler would cause air to be locked in some of the pipes, and small as this trouble may sound, it will be found to be a very real cause of vexation and expense before it is put right.

It is the custom to put a dip—or syphon as it is wrongly called—in the cold service pipe, the purpose of this dip being to prevent heated water working up the service pipe to the supply cistern. Heated water, it will be found, will circulate up a single pipe when it runs vertically (see p. 20), but if the pipe, where it first receives the hot water, is dipped a little, i.e. descends a little, this proves a barrier to the circulation that can occur wholly in a single pipe. In very many cases the fact of some warm water circulating up the cold pipe is no fault. It comes either from the bottom of the boiler or from a return pipe, but it seldom does harm. Should a dip be

needed, however, then it should not exceed 6 in. in depth, and it must be made at the lower end of the cold supply pipe, as either of the examples in Fig. 22. This shows the cold pipe joining a return near to the boiler. *The dip should never be made as Fig. 23*, for it costs more unnecessarily and may get air-locked. On no account should this double bend, or any form of dip or syphon, be put high up the pipe near the cold cistern. This is a practice that will almost certainly cause trouble. Fig. 22 should be considered the only correct way of making the dip (either into a return as shown or direct into the boiler), and if the dip can be omitted altogether it is better still.

It is the rule to run the cold supply service by the most

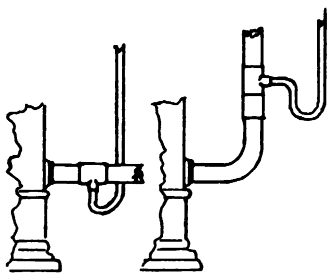


FIG. 22.

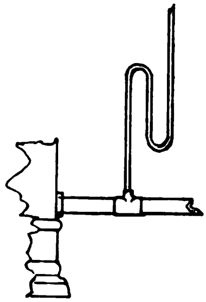


FIG. 23.

direct or easiest route to the boiler, but some care should be exercised to see that no dips or sags occur in its run. As a rule it is run in iron tube, but should lead pipe be used it must be run on wood fillets where necessary, and precautions taken to let it have a slight fall all the way towards the boiler. Air is quite an enemy to the heating engineer, and, with the novice, it sometimes seems to lie in wait to trip him up. It must be remembered that if air cannot get away easily it will, of course, stay and collect. If the apparatus had large taps on it that were opened occasionally (as with the domestic hot water supply to baths, etc.) the air would be swept out with the rush of water through the pipes, but there is no such assistance here, and a little collection of air will stop even the

water passing through the cold service pipe after the apparatus is charged and in use. An apparatus loses such a little water by evaporation that there is no rush to dislodge the air. There may be only a quarter of a gill or even less pass down the cold supply per day, and any place where air can collect will lock this pipe as readily as it will stop a circulation. This is explained more fully under AIR IN PIPES.

The size pipe best suited for the cold service is generally left to the engineer's judgment, but there should be some rule to work to. The last paragraph will show that an $\frac{1}{8}$-in. pipe would serve quite well as regards supplying the small quantity of water a medium size apparatus requires, but $\frac{1}{2}$-in. is the smallest size that should ever be used. It is the fact of a small pipe being readily choked, or stopped by dirt or rust, that precludes its use; and the following is a rule that may be worked to (unless larger is preferred or specified):—

For works having this radiating surface	The cold supply service should not be less than
Up to 250 sq. ft.	$\frac{1}{2}$ inch.
250 ,, 500 ,,	$\frac{3}{4}$ inch.
500 ,, 1000 ,,	1 inch.
Above 1000 ,,	1 inch or $1\frac{1}{4}$ inch, according to conditions.

When a stop-cock is put into the cold supply service, it is put near to the boiler, and it should be of a pattern that has a full way or bore through it. A gate or Peet's valve is generally used, but in certain cases it may appear best to use a cock with a removable key; but whatever kind is used, it should have a clear straight way through it equal in size to the pipe it is attached to.

A near neighbour to this stop-cock—when it exists—is an emptying cock. This has always to be put. There is no rule as to size, but one or two shillings spent in an extra size is often saved if an apparatus has to be emptied once or twice before the job is finished. If the apparatus is anything but a small one, it is an economical plan to have the nose of the cock provided with a hose union. A piece of hose is then attached, and taken to the nearest open gully or other con-

venient spot. It saves the carrying of, possibly, hundreds of gallons of water in pails. From ½-in. to 1-in. (full-way, if possible) are the sizes of cocks ordinarily used, but there is no limit in largeness.

Every radiator, or run of radiating pipe, has an air-vent at its highest point. In horticultural works it may be said that this always takes the form of a piece of ¼-in. or ⅜-in. pipe, as this needs no attention at any time. But this is seldom possible in brick buildings, and the air-cock is in general use. These will be found described in the chapter devoted to FITTINGS.

Every heating boiler, small and large, should have a Safety-Valve. These are also described under FITTINGS, but a rule may be suggested here as to sizes.

A boiler having a catalogue heating power as under	Should have a safety-valve of this nominal size
Up to 400 ft.	¾ inch.
400 „ 600 „	1 inch.
600 „ 1000 „	1¼ inch.
1000 „ 2000 „	1½ inch to 2 inch.

In giving the nominal size of safety-valve this means that, for instance, a 1-inch valve has seldom a 1-inch clear way through. Nominal size, therefore, means catalogue size. Reference to safety-valves in the chapter on FITTINGS will show that the lever safety-valve is recommended. It is simple and, rather importantly, its price does not rise out of all proportion in the larger sizes. With some makes of valves any size above 1-inch is quite a tax on the profits.

The last detail that may be explained is that of charging the apparatus with water when its construction is finished. As mentioned more than once, the chief object to be attained is to fill the whole of the pipes and parts with water; and, to effect this, all air must be expelled by the water as it enters. The expansion pipe is the chief air-pipe, but this may not give vent to the air that is in the branch circulations. A very important thing to remember, therefore, is to have all air-cocks on radiators, or pipes, open when the water is coming in. This means of course that a little extra help may be needed for

part of an hour, as a man and mate cannot watch several radiators in different rooms at once, so as to shut the air-cocks when the water appears. It should however be managed somehow; for, to charge an apparatus with the air-cocks closed will, in quite half the cases, result in air-lockage at some point or other. (See AIR IN PIPES.)

Further general details will be found in the succeeding chapters, details which appear in the more advanced work described there, and which cannot be referred to so well here. The reader is recommended to peruse the particulars given with the example works illustrated there, particularly with the first example which, in a large measure, forms a continuation to this chapter.

CHAPTER V.

EXAMPLES OF LOW-PRESSURE HOT-WATER HEATING APPARATUS FOR BRICK BUILDINGS.

IN stating that these example works are for *brick* buildings, it is intended to convey that the buildings are not glass-houses or similar horticultural structures. Brick buildings, therefore, include everything, from a small residence or a workshop, to a large factory or block of flats, or any large building. The limited number of examples that can be given are as representative as possible, and, although not meeting every requirement, will serve to guide the student when planning works for practically any kind of building. It is probable that none of the following schemes of work can ever be copied exactly, for every engineer knows that two jobs are rarely, if ever, alike; therefore, the principles of the different systems is all that can be suggested or taught, and these have to be adapted to the works that the student has put before him.

There are three systems of work in general use—viz. the two-pipe system, the one-pipe system, and the overhead system. There occur modifications of these, as an engineer will find—conditions which require the strict rule of the system to be modified. It will also be found that an apparatus may easily have all three systems embraced in it, the conditions, again, making this desirable. There is nothing confusing about this, as any one practising the work quickly finds. In addition to the methods named, there is the high-pressure or Perkins' system, but this is quite different, and as it never forms part of a low-pressure system, it is treated separately, and forms the subject of a later chapter. What is termed in-

direct or direct-indirect work only relates to a special kind of radiator used, and description will be found under RADIATORS and in other places. Horticultural work is treated separately, but has its connections nearly always on the two-pipe system.

For the general description of the parts of an apparatus, the reader is referred to Chapter IV., which is wholly devoted to this.

THE TWO-PIPE SYSTEM.

This is the oldest method of carrying out these works, and its name is derived from the fact that the radiators (or coils or rows of pipes) * are connected to both flow and return pipes of the main circulation. It may be explained here that in all systems the main circulation has a complete main flow and return circuit, and as regards the two-pipe and one-pipe systems, the difference is chiefly in the method of connecting the radiator branches. This difference, however, introduces others, as will be seen later.

Figs. 17 and 18 (pages 38, 39) illustrate a two-pipe system of apparatus in a simple form, while Figs. 24 and 25 give a somewhat larger example in which more detail appears. In this the flow pipes appear as solid lines, while the returns are broken, i.e. dotted. This shows the ground floor of a residence which is to be fully heated, except in the dining room where auxiliary heat to the fire only is required. This means that one radiator is fixed in that room instead of two, the radiator being of about two-thirds to three-fourths the total surface that would be required if the room had no fire.

The main circulation is carried beneath the floors of these rooms, which means that the boiler must be in the basement, or sunk below the floor level by some means. Every effort must be made to effect this, as it facilitates the work so greatly ; and so far as the two-pipe system is concerned it is

* It will be found that most of the following suggested example works show radiators as the heat-distributing surfaces. This is because so few works are now carried out wholly with pipes (except in horticultural buildings, which form the subject of a separate chapter).

absolutely necessary. If the boiler is not below the ground floor, then only the one-pipe system is possible, and an example of this (the writer's own house) will be found given later.

Assuming the pipes are below the ground floor, then all

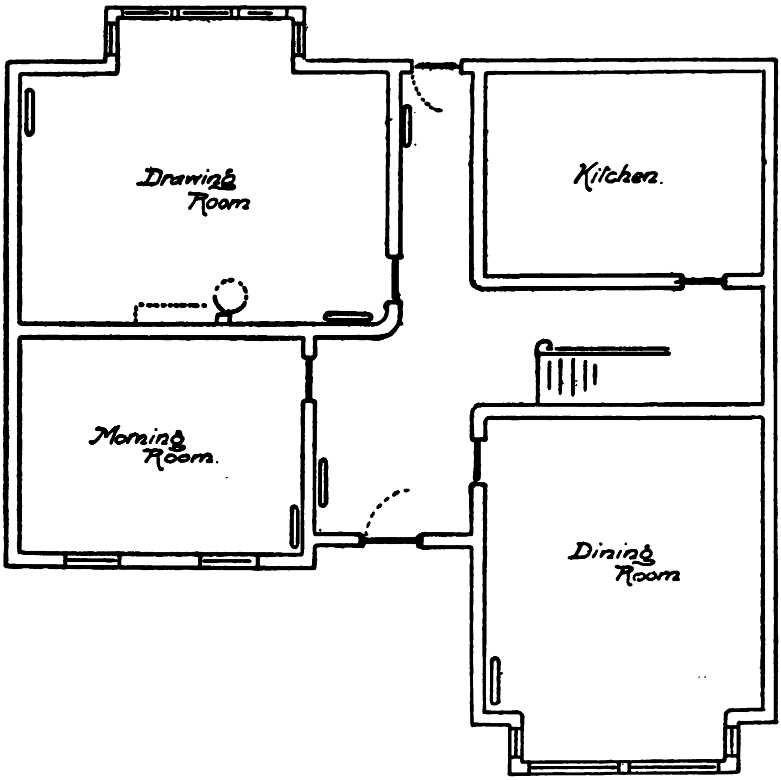


FIG. 24.

radiators can be connected without any pipes being visible above the ground floor. This is an excellent feature, as visible pipes have done much to prejudice this mode of heating, particularly in residences and buildings of this kind. People are quite commonly heard to say that they dislike hot-water heating works "because of the ugly pipes." Students

—and engineers—should therefore consider it an essential in good work that no pipes are made visible. There may be three inches of small pipe to be seen—but only by looking for it—where the connection to the radiator comes through the floor, but nowhere else. When pipes have necessarily to go up angles, or along a wall, then the lines must be carefully chosen, and the piping afterwards encased. Visible pipes are always objectionable, and this should never be forgotten. Of

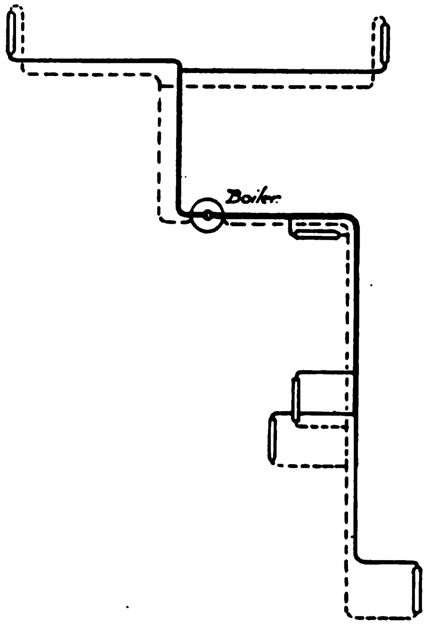


FIG. 25.

course in factory, warehouse, or similar work, visible pipes are not objected to, and in such cases the circulating pipes are often counted on to represent so much heating surface, but in residences, and all good class work, the pipes must be hidden, and also covered to prevent loss of heat. (See COVERING PIPES.)

The question of visible pipes has an important bearing on the method of connecting up radiators. Where pipes come

through a floor to a radiator, there is only one proper manner of connecting to it, and this is by means of an Angle Valve at one end, and a Union Elbow at the other end. It is seldom that a radiator is without a valve at one end, but should it be omitted, then a union elbow had best be used at both ends. These valves and elbows are illustrated in the chapter on fittings, while Fig. 26 will show their application as now recommended. It will be seen, also, that if the valve has a union upon it, the disconnection of the radiator is simplified.

An engineer does not practise this work long before he

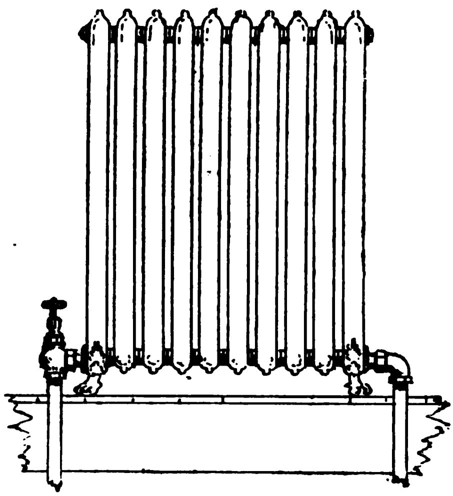


FIG. 26.

finds that his pipes and radiators have to be in and tested before a house, or other building, is decorated. He is then asked to take his radiators down, that the walls behind may be papered or coloured, the skirtings painted, and the back of the radiator itself given at least one coat of paint. After this, at a suitable moment, the engineer is asked to put the radiators back. It needs no explanation to show how convenient union connections are, and how much injury they save. As practically all these union fittings have coned faces, the desirability of a branch service not being rigid (see p. 40) will be under-

stood, as one of the pipes must be sprung back about a quarter of an inch to get the radiator free after the nut of the union is undone.

Referring again to Figs. 24 and 25, assuming that the first floor (the floor above the ground floor)* requires warmth in addition to the ground floor, then the best plan, whenever possible, is to carry branches up to the radiators from the mains in the basement rather than attempt running mains under the boards of the upper floor. What is suggested would be done as Fig. 27, the ascending pipes being carried up in a chase in the wall, or up in an angle and cased in. If two or three radiators could be connected up to one rising branch service, as Fig. 28, without seriously cutting the joists, then it might be done with advantage; but attempts to run a pair of fair sized mains, probably 2-inch, beneath the boards of a first floor is seldom possible, and more seldom allowed by an architect.

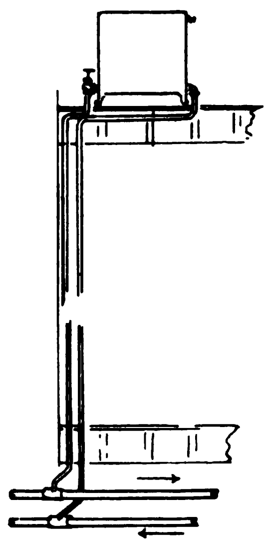


FIG. 27.

A detail in house warming which requires full consideration is the disposition of the radiators. As previously explained the radiator, notwithstanding its name, affords most heat by warming the air; and this, although there may be a general idea to the contrary, is where it does excellent work, and makes hot-water heating the source of real comfort that it is. It is therefore necessary that whatever cold air enters the house shall, at the earliest moment, have contact with the radiators; for, failing this, the space occupied by

* American readers may be informed that in England the floor which is level with the ground, or thereabouts, is called the ground floor, while the floor above it is termed the first floor and so on. In America the first floor is that which is at the ground level, the second floor being the next above it, while the floor beneath the ground level is the basement. They have none termed the ground floor.

unwarmed air will be disagreeable to the occupants, and a source of complaint.

Where does the cold air enter a house? All houses have chimneys built in them, one to each important room, and these chimneys, although unused, have draughts in them sufficient to keep up a full proper change of air. Ventilation, i.e. a change of vitiated air for new good air, is highly important in all buildings; and, as stated, chimneys make excellent extractors. But where does the new air enter the house—very cold air in winter—and which is usually described as cold draughts? As residences are but rarely ventilated on any good principle, it will, in almost every case, be found that the new air which makes good the volume extracted by the chimneys enters through the crevices around the front and back entrances,

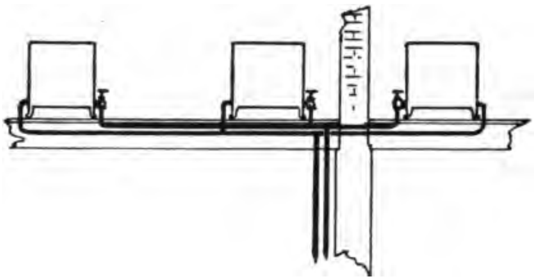


FIG. 28.

also around any ill-fitting window or other place that affords a passage for air from outside to inside the house. It scarcely matters where an opening exists in the outer wall of a house, or its size or shape, but what an in-current of outer air occurs through it. This is due to the extracting qualities of the chimneys.

Having realized that cold air enters in considerable volume by the routes named, radiators should be disposed to intercept it and take its coldness, and its ill quality as a "draught," from it. In the illustration Fig. 24, it will be seen that a radiator is placed near the front and back entrance doors. These are important situations, if the house is to be properly warmed. There are houses in which it appears possible to almost warm the whole building if the ground-floor halls or

entrance-ways were equipped with sufficient heating surface. In all cases there has to be extra surface here, and even then they are the coolest places in the building. By referring to the chapter entitled QUANTITIES, it will be found that the highest figure for a given space is against entrance-ways, and it may be explained here that the special quantity is needed because it does two services, viz. warming the hall to a reasonable temperature, and partially warming the air that goes to the rooms and other parts of the house. It is particularly recommended that full surface be used in those places, for, failing this, the whole job must be in a sense unsatisfactory, affording a feeling that all is not quite right, or that an improvement was possible somewhere. It need never be thought that entrance-halls or corridors can be overheated. It might not be an impossible task, but it is doubtful if anyone has done it yet.

In the different rooms the radiators are placed where they are supposed to do best service. It will be seen at once that the writer does not favour placing radiators under windows. They doubtless do good work there, but they waste much heat and give a diminished result elsewhere. In good houses the windows are not very draughty; in fact, their yield of cold air through crevices around them is almost imperceptible. What little air does enter may come mostly between the middle rails and this does not produce any uncomfortable feeling. There is, however, always a downward fall of cool air from a window, this being due to the cooling influence of the glass—the rapid cooling and making heavier of the warm air that comes against the glass. This is remedied by placing a radiator beneath the window, but the writer considers the remedy the reverse of economical in heat, for most of the warm air rising from the radiator must come against the glass, and this is, to some degree, like trying to heat the outer air. In rooms properly—i.e. sufficiently, and efficiently—warmed by radiators placed in other positions, no inconvenience is experienced by the cool air of the windows, for it is possible to sit near a window without discomfort.

The practice of putting radiators beneath window seats

has very little to recommend it. The seat stifles the work of the radiator (for it is like putting it in an open-fronted box); the warm air cannot rise freely from it; it is doubtful if the falling of cold air at the window is neutralized, and, lastly, it is not agreeable to occupy a seat with a hot radiator beneath it sending out warmed air in front.

While on the subject of disposing the radiators, it may be mentioned that the not uncommon practice of heating a billiard room by placing a radiator beneath the table must be condemned. If the radiator is powerful enough to heat the room, it is powerful enough to injure the table; but apart from this, it will be found that players, as they lean on the table, feel an irritating current of warmed air rising beneath their faces. Briefly, billiard rooms should be heated as other rooms, and although the exercise of the players makes less radiation necessary for them, yet it is customary to put in sufficient for 60°, as lookers-on need this temperature for comfort.

In disposing the radiators it is not important to put them near the doorways inside the rooms (to intercept the entering air), if the halls are properly warmed. In the halls, as already stated, the cold outer air that enters there should receive warmth as soon as possible; but when this is done the positions of the radiators in the rooms should be chosen with the knowledge that they warm the air, and send this circulating across or about the rooms. If no other currents disturb the air movement, it will be found that cool air will always be moving towards a radiator at a low level, while warmed air ascends from the top of the radiator, and travels towards and to some extent along the ceiling. Fig. 29 will give an idea of this, the broken lines indicating air movement.

As stated in another part of this book, the writer has for some years lived in houses heated by hot water, and has, naturally, been able to note any good or poor results, that is, any noticeable difference in results, obtained with radiators fixed in different positions. The outcome of this is that some certainty is felt that the best work is done by radiators placed against a solid or blank wall (a wall without a window or opening in it), and facing a similar wall. It is not requisite

that the radiators be placed in the centre of the wall, and experience seems to show that they are best put at that part which comes nearest to a wall with a window in it. The radiators in the Dining Room and the Morning Room of Fig. 24 will show what is meant, these radiators being on blank walls and facing blank walls, but moderately close to those walls which have windows in them. The writer has no theoretical argument to back up his conviction, but experience has shown it to be so reliable that it is felt it may be recorded here. Of course all this is based on the understanding that the halls, or outer places, on which the rooms open, are properly heated.

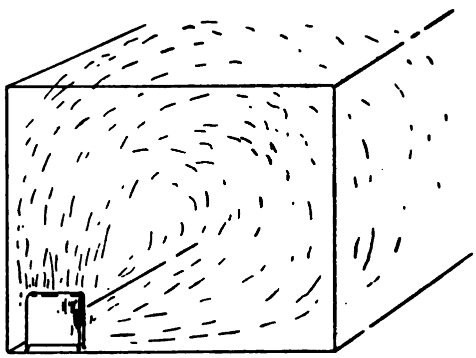


FIG. 29.

A final detail of Fig. 25 that may be discussed is the boiler connections. It will be seen that the main flow pipe leaves one central point at the top of the boiler, that is, starts as a single vertical pipe which is branched just above, while the returns do not join one another, but enter the boiler separately one on each side. Fig. 30 will give an idea of this.* The lesson to be learned from this is, that while a main flow pipe may be branched (as many times as its size and the general circumstances will permit), every effort should be made to

* It is not absolutely necessary that when two or more returns enter the boiler that they should be as distant from one another as possible, but it is good practice, and should be arranged so when it can be done.

bring returns home separately to the boiler. Of course this is not always possible; but when it is, the circulation will be found to proceed more freely in each, and make regulating valves less necessary. An even better plan with Fig. 25 would be to let the two main circulations have both flows and returns separate.

One well-known London engineer appears to try to get a separate circulation from the boiler to every two or three radiators, or as near to this as he can. In a large job it makes a maze of pipes, and much extra expense, but there need be little hesitation in saying that he gets the freest possible circulation to every point on every occasion. Opposed to this, the writer occasionally meets instances in which a man delights in getting all his work on one pair of pipes from the boiler, showing all his skill in a multiplication of branch circulations. Very few such works, when they are at work, fail to show that the engineer lacks experience.

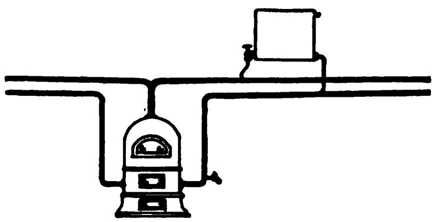


FIG. 30.

Another example of work on the two-pipe system may be given in Fig. 31. In this it is supposed that the boiler faces the reader, and, while two separate flows leave it at the top, two returns will be seen entering separately near the bottom, one each side. It will be seen that the apparatus is incomplete, but sufficient is shown to indicate what may be done. It is an apparatus that might appear in a business or public building of several floors, the rising branch circulations (or sub-mains, as they are sometimes called) having the radiators on them, while the chief main circulations are in the basement just above the level of the boiler. There is practically no limit to the number of mains that might be run in the

basement (according to the size of the building), and the apparatus lends itself to dealing with any number of radiators.

A detail of importance is the plan adopted in connecting the rising branches to the basement mains. It is not desirable that they be connected by tees "looking upwards," as it is termed. If these branches start vertically, it will be found difficult to get the circulation past them in a satisfactory manner without the aid of stop-valves very nicely adjusted. In any case it is the custom to put valves in these branches, but every effort should be made to get the circulation to work as equally as possible at all points. The difficulty experienced when stop-valves have to be so carefully set to adjust the circulation is, that a variation in the firing will vary the results;

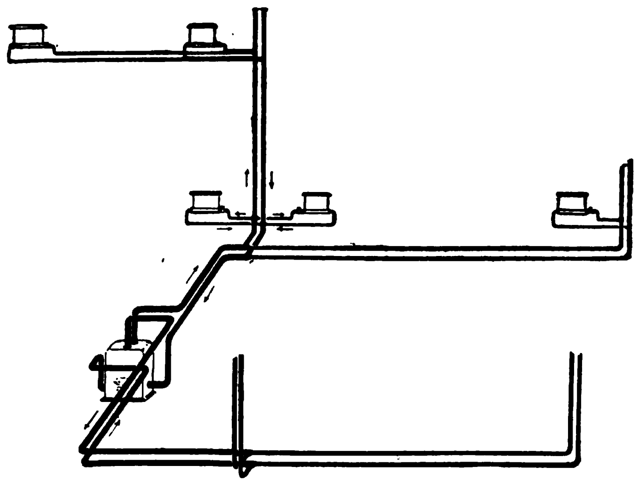


FIG. 31.

and if the valves are accessible to servants, they regulate them according to their own ideas, and, needless to say, complaints quickly follow. Let it be repeated, every engineer should arrange his branches, set out and proportion his work, so that the apparatus will be as independent of regulating valves as an apparatus can be. What valves are used should have removable keys, if in a private residence, and only some-

one understanding hot water circulations, such as a gardener, be allowed to use them.

As stated, if vertical branches of any importance are taken from horizontal mains, much care and the best judgment should be used as to connections. It is not too much to say that the work past the branch can be wholly cut off and dead, if sufficient want of care is shown. Therefore, let such branches start horizontally, as the illustration Fig. 30 shows, and only with branches which run horizontally should the outlets of the tees, which make the connection, look upwards. Of course, any angle between vertical and horizontal can be adopted with the tees, according to the engineer's judgment, but considerable practice, and usually some doubtful results, are required to make a man skilled in this.

While on the subject of stop-valves (for regulating purposes) in branch circulations, a good plan when the branches carry much work, and the cost will admit, is to put two stop-valves * in the branch, one in each pipe, and just above the valve in the return pipe insert an emptying cock. The idea is to be able to shut off and empty a branch—a section of the apparatus—and effect any needful repair without emptying the whole or putting the fire out. Whatever happens to a heating apparatus—whether the leaking of an air cock or something greater—always occurs when the apparatus is in use, and the suggestion just made enables any such trouble to be remedied with the least possible inconvenience and cost.

No cold supply service is shown in Fig. 30. This would be connected into one of the returns near the boiler, or into the boiler itself. Full particulars, with suitable sizes of pipes, are given on pp. 43–49.

In regard to the expansion pipe, it is a commendable plan to put more than one on an apparatus of large size. On that illustrated, Fig. 30, there might be two, while still larger works might have three or more. It might be roughly

* It should be the practice with every engineer never to put any but gate or Peet's full-way valves in circulating pipes. These valves do not reduce the area of the water-way, and the water goes in a straight line through them.

reckoned that one to each twelve to fifteen radiators would be a proper number, though more than one is seldom absolutely necessary.

SIZES OF MAIN PIPES.

TWO-PIPE SYSTEM OF APPARATUS.

Sizes of mains run horizontally.	Will carry this radiating surface.
1¼ inch	75 square feet.
1½ ,,	140 ,,
2 ,,	270 ,,
2½ ,,	480 ,,
3 ,,	750 ,,
4 ,,	1300 ,,

Note.—All circulating pipes must be counted as radiating surface if they are not covered.

Vertical mains or branches will carry more radiation, therefore a size less pipe may be used for these ; thus 480 feet of radiation may be put on a 2-inch vertical circulation, and at no time is it well to have vertical branches over-large in proportion to the size of the horizontal mains.

RADIATOR BRANCHES AND CONNECTIONS.

Size of pipe and stop valve.	Heating surface of Radiator.
¾ inch	up to 20 feet.
1 ,,	20 feet to 48 feet.
1¼ ,,	48 ,, 80 ,,
1½ ,,	above 80 feet.

Note.—It is assumed that radiator branches do not extend horizontally for a greater distance than from 8 feet to 15 feet, according to size of pipe. When the horizontal distance is greater, a size larger pipe should be used.

An arrangement of piping possible with the two-pipe system of apparatus, is that of reducing the size of the pipe

as the work is passed; thus, if a 3-inch pipe is necessary at the boiler (to carry, say, 700 feet of work), it need not be carried in this size to the most distant point of the apparatus. As

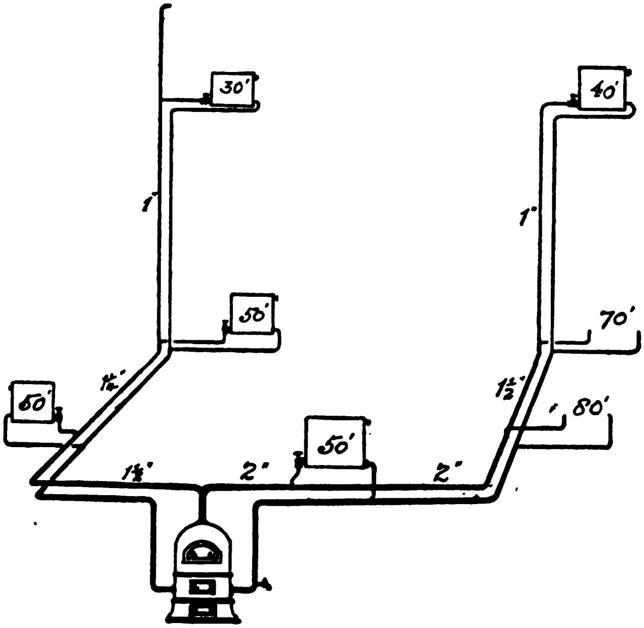


FIG. 32.

branches and work are passed, a size of pipe may be used which is suited for that beyond and no larger. A clear idea of this may be gained from Fig. 32.

CHAPTER VI.

EXAMPLES OF LOW-PRESSURE HOT-WATER HEATING APPARATUS FOR BRICK BUILDINGS.—continued.

THE ONE-PIPE SYSTEM.

THE meaning of the term "brick buildings," used in the title of this chapter, is given at the beginning of Chapter V., on page 52, in which chapter the two-pipe system of apparatus is described. For the general elementary details of a hot-water apparatus, of any kind, see Chapter IV, page 37.

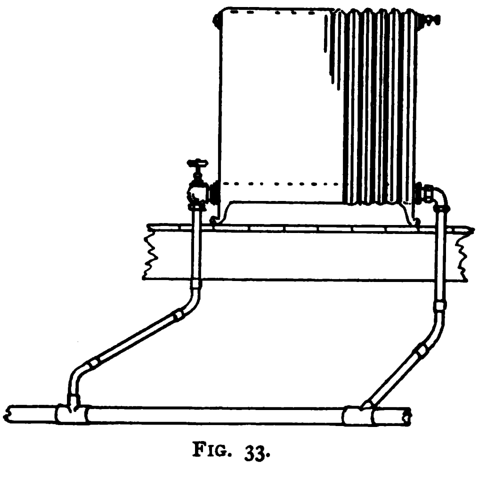


FIG. 33.

THE ONE-PIPE SYSTEM of apparatus has a flow and return circulation in its mains and branches, much the same as the two-pipe system, but as its radiators are connected to one main pipe only, much variation in the work and general

planning is possible. It is, however, the fact of the radiators having both their service branches connected into one main pipe (instead of two) that gives this system its distinctive name. To make this clear, a sketch of a radiator, as ordinarily connected up, is given here (Fig. 33), but the description will be given later.

It is somewhat probable that now the one-pipe system has become universally understood, more work is carried out on this principle than any other. Its convenient details lead to

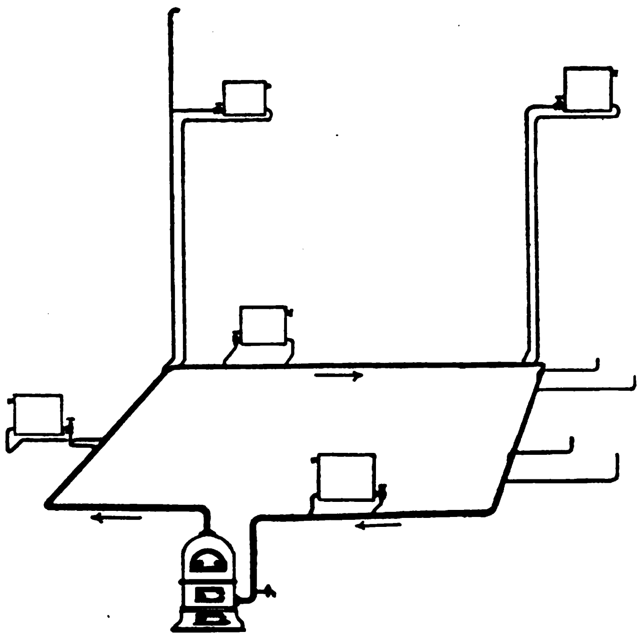


FIG. 34.

this being done—as will be seen very clearly if this chapter is read through—and the convenient features which are so obvious are commonly associated with a reduced cost in the work as compared with a two-pipe apparatus.

Taking Fig. 34 as an example apparatus to describe the detail from, this, which is a perspective outline of the piping, shows a boiler in a basement or pit, and a single main circuit starting from the top of the boiler, extending around a base-

ment ceiling (or beneath the joists of a ground floor), and returning to the boiler after making what might be a complete circuit of the building. The arrows indicate the direction of the circulation.

One thing that will be noticed is that there can be no short-circuit (see p. 41), and no radiator can well be neglected. It must be acknowledged, however, that if the main pipe is too small the last radiators will not heat successfully, but this is a result to be expected with all systems.

The main circulation is of one size of pipe at all points; that is to say, if it starts 3-inch from the boiler, it keeps this

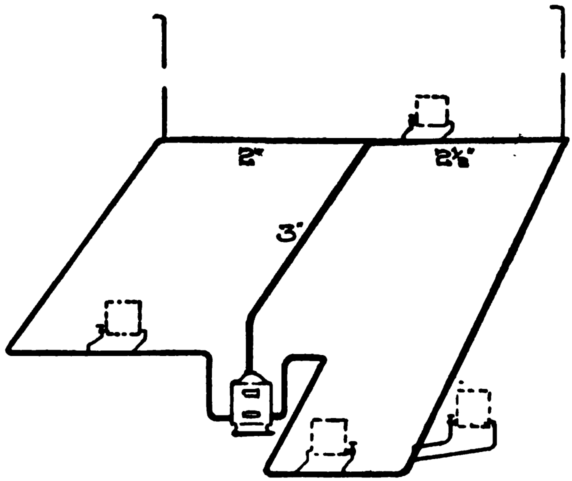


FIG. 35.

size all the way—and cannot be reduced as the work is passed, as it is with the two-pipe system (see p. 66). Of course, if the main is branched, then it would probably be reduced, as Fig. 35 will serve to show, but with one or more unbranched circuits (and there may be several from one boiler if desired) each one is carried round all the way in the size of pipe it starts with. The reason for this is easily explained, for it will be seen that the water from the radiators returns into the one main pipe, and the latter has, therefore, to act both as flow and return for a greater part of its length. If the water

was visible at about half the distance round a circuit, it would be found that the upper part of the pipe contained the hottest water—to serve the radiators as yet unserved—while the lower part of the pipe contained cooler water, viz. that which has been through the first radiators and has lost some of its heat. Even the application of the hand to a one-pipe main, when it is a full-sized pipe, will show that, in parts, it contains two distinct strata of water, the hottest unused water at top, the cooler used water at bottom. With the two-pipe system the cooler used water at once returns to the boiler, and, therefore, the main service pipes may be reduced as the work is passed, but with the one-pipe system the used water travels on with that which is unused, and the bulk at all points remains the same. As stated, therefore, one-pipe main circuits are carried from beginning to end in the size of pipe they commence with, and are not reduced in size as the work is passed.

The particular kind of job in which the one-pipe system excels is when the work lies to a large extent around the sides of a building. It then means that a single pipe may be carried around the basement about four to six feet from the outer wall, and this one circuit will take all the work, in the way that Fig. 34 shows. Or, if more convenient or desirable, the circuit can be started as a single pipe, and then be branched and returned as two, or more, circuits, as Fig. 35; or, again, there can be two or more distinct circuits from the one boiler, not associated or connected in any way, except for the fact that the one boiler heats the water they contain. In certain cases there may be a circuit to serve a ground or lower floor, while another circuit around the ceiling of the latter will serve the radiators on the floor above. In such a case the higher of the two circuits will probably have the fastest circulation, and will need a valve to check it.

Unless, when two or more floors have to be heated, the conditions make it preferable to run a separate circuit to each, there are usually no objections to heating the radiators of the different floors from the one basement main, as Fig. 34. In that illustration it will be seen there are two radiators

occupying much higher situations than the others, and these will be served quite as well as those at the lower level. It means, of course, carrying several pairs of pipes up the least conspicuous angles of some of the rooms, if there are several radiators upstairs, but this may be preferable to a main circuit around the ceiling, or beneath the floor boards. In suites of offices, or business premises, there is less objection to pipe-casings in angles of rooms, and in such cases several radiators, one above the other, may have their connections as Fig. 36.

Referring again to the example apparatus, Fig. 34, it will be seen that the main circulation must have a highest point, that is, it starts from the top of the boiler, and proceeds around the basement with the customary rise of not less than one inch in ten feet, but it must commence to descend somewhere to reach the boiler again. The customary practice is, starting with the flow pipe from the top of the boiler, to give this a rise until it is about half way round, and then to let it descend the rest of the way back to the boiler. The highest point then is somewhere about as far from the boiler as it can be, and the pipe from the top of the boiler to the high point is known as the flow, while the continuation of it from that point is considered the return.

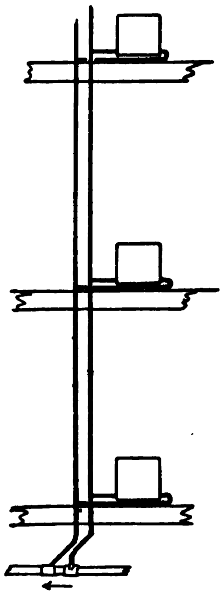


Fig. 36.

A good practice, and which should be considered essential, is to put only half, or less than half, the radiation on the flow, while the remainder is on the return. To do this it follows that the highest point cannot always be exactly half-way out from the boiler, and this is why it was stated it would be *about* half-way. As a matter of fact, however, the highest point is often much nearer to the boiler. What has to be considered is this: That both the theoretical and practical explanation of the action of convection proves that the move-

ment, and the most effective movement, is obtained by studying the return pipe. The actual motive power lies in the return, and this is owing to its carrying the coolest water. Therefore, to load the flow pipe (of the one-pipe system) with radiation more than the return is to court a certain degree of failure, for the simple reason that all radiation is simply water-cooling surface. Radiators are fixed expressly to lose the heat of the water they contain, therefore there should be at least half of them on the return main or more. Occasionally instances are met with in which this argument appears to be weak, as a greater surface on the flow of a circuit is found to work satisfactorily. The writer must admit he has risked it himself when conditions made it imperative, but the fact remains that however well such an apparatus worked, it would have done better had the greater share of work been on the return.

On the highest point of a horizontal one-pipe circuit (as Fig. 34) there must be provision for the escape of air that will collect there. Air is always collecting in pipes, quite apart from what may gather at high points when filling, and it must have free escape. On this account it is customary to put the expansion pipe on the high point; and if the general conditions admit, the high point may be arranged to suit the expansion pipe. When, however, they cannot be brought together, the expansion pipe may be anywhere on the flow length of the circuit, but it is then necessary that a radiator be put on the highest point. A radiator allows of a fair volume of air collecting in it without impairing its efficacy, and may only require its air-cock to be opened a few times during the winter season, although it takes all the air of the main circulation. It will not do, however, to have neither expansion pipe nor radiator on the high point, and only trust to an air-cock there. The cock would require opening at least every week, and would often be neglected. It is never impossible to arrange the high point to come convenient for a radiator or expansion pipe.

In connecting radiators it is considered best to let the flow or hot connection come vertically from the main by a tee,

with its outlet looking upwards, while the return is best if connected by a tee with its outlet horizontal. Fig. 37 (which is a copy of that given on page 67) shows these connections, and their utility is based on the fact, already referred to, that in a one-pipe main the hottest water is carried along the top of the pipe, while the cooler water (which has passed through radiators) travels beneath it. This being so, the reason of the top connection for the flow branch is obvious, while the horizontal return branch delivers its used water in the best possible manner to prevent its mixing with or otherwise prejudicing the hottest water at the top of the pipe. Here again,

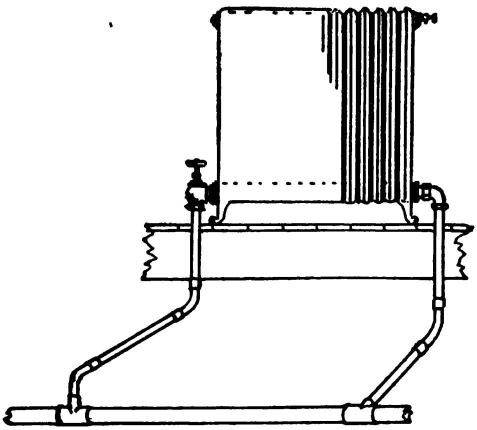


FIG. 37.

however, arises the fact that many jobs have been done with both connections made by tees looking upwards, and good results have been obtained; but it remains best to make the connections as first stated whenever possible.

When an apparatus on the one-pipe system is being first or newly heated up, or the heat of its water increased, it will be noticed that nearly all the hottest water appears to enter the first radiator branch, and not work beyond this until the first radiator is quite hot. After this the section of main between the first and second radiators gets hot, but stops for a time at the second radiator branch and so on. Each radiator branch

acts as a temporary stopping place in the heating of the main circulation. This, as stated, only occurs to a noticeable extent when the apparatus is being heated up, yet it occurs to some extent at other times, particularly if only a moderate fire is being kept when, say, the outer air is 42° to 50° Fahr. At these times, although the apparatus is not being newly heated up, but is performing its normal and regular duty, there is often too great a difference in the temperature of the first and last radiators on a circuit.

The object of referring to this is to suggest that when the conditions appear to make it advisable the branch connections to the first, and sometimes the second and third, radiators might be made wholly with horizontal tees—neither the flow or return tee looking upwards. Considering that the flow main, when it leaves the boiler, is full of the hottest water, there is no necessity for an extreme top connection for the flow branch of the first radiator, and by adopting this plan it will be found that the more distant radiators do better.

It must not be thought, however, that this detail amounts to being a fault of the one-pipe system, for when an apparatus is in full work in cold weather, all radiators are, or should be, thoroughly hot. Of course, with this system as with others, the best uniform results depend to some extent on regulating the radiator valves. If there were say eight 35-feet radiators on a circuit, the valve of the first three, however they might be connected, would be closed to some extent, so as to favour the more distant ones. The writer's common practice, whenever the conditions appear to admit of it, is to put smaller branches and valves to the first radiators. Some care has to be exercised in this, but in the case of eight 35-feet radiators, it is probable that the two first would be given ¾-inch branches and valves instead of the 1-inch that is customary for radiators of this size. It is astonishing how much the valve of a first radiator can be closed before the full efficient heating of the radiator is interfered with. In the writer's own house, the valve cannot be open more than $\frac{1}{16}$-inch, yet the first radiator, of 32 feet surface, heats most perfectly. It is only a ¾-inch valve, too.

Another method of carrying out the one-pipe system of work may be illustrated in Fig. 38. This is truly an example of the overhead system (to be next described), but as it is confined to one floor, it may be shown here. It represents the heating of one floor by a boiler which has to be fixed level with the floor that the radiators stand upon. This is not an infrequent demand, as it has often to be done in suites of offices, and in suites of rooms (flats), which are all situated on one floor of a building; and in the writer's own case it was adopted to heat a one-floor bungalow, which had no basement or cellar, and which was on soil that made a boiler pit impossible. The boiler, however, was sunk about two feet, but this still made a one-foot rise necessary for the return pipe to enter the water-way of the boiler. There were twelve

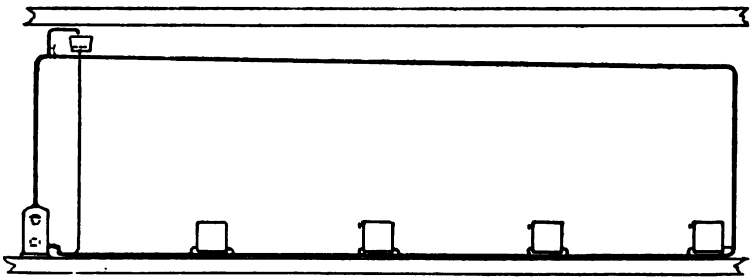


FIG. 38.

radiators on the return pipe, which, in this case, was carried beneath the floor joists. In suites of offices, or rooms, the return has either to be carried above the floor, or in notched joists beneath the floor boards, as it is probable that there are other offices or rooms below.

It will be seen that the flow pipe is carried as high as possible immediately it leaves the boiler, and then proceeds in a horizontal direction until it is about over the furthest radiator. The flow pipe, having no work on it, can have its highest point either over the boiler or at its distant end, as may be most suitable; but wherever it is, it must carry the expansion pipe there.

A difficulty that arises is in the fact that when the offices

or rooms are confined to one floor the flow pipe cannot be carried up to the ceiling and encased there, but must be some 12 inches down, so as to come below the necessary supply cistern, as shown. If it is possible to have the cistern above the ceiling, then the flow pipe can be carried higher; and, in the case of the bungalow just referred to, the flow was carried along on the ceiling joists in the roof. In a self-contained suite of rooms, however, the flow pipe must be carried along the wall, about a foot below the ceiling, unless some special condition allows of it being put higher.

A final example of an apparatus on the one-pipe system

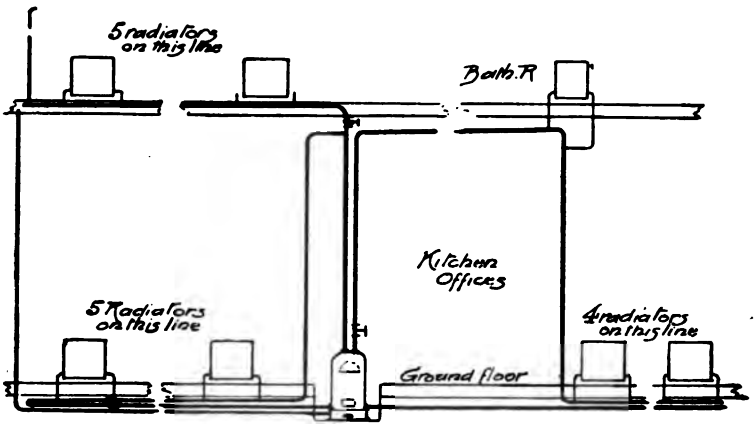


FIG. 39.

may be given in Fig. 39, this being in the writer's present house, and presenting some unusual features. It is a house of two floors, but without a basement, or any convenience for getting the boiler below the ground floor. It was possible to get the boiler sunk in the floor of an outhouse sufficiently to let the returns be connected without rising, but it could not be sunk low enough to get the flow pipes beneath the ground floor without unusual expense.

In this it will be seen that two circulations start from the top of the boiler. That on the right was carried along the ceiling of the kitchen offices, and could, fortunately, be given

an air vent on its highest point by the bath room radiator coming there.* It then dropped in the angle of a lobby (between kitchen and dining room), and was carried beneath dining and drawing room floors and home. The left hand circulation was branched near the ceiling, and served the greater part of two floors. It is almost needless to say a valve had to be put to prevent the upper floor taking the lead.

In this case, and as has been so strongly recommended in an earlier chapter, the boiler, though having but two flows from it, had three return connections. A flow pipe, if of suitable size, may be branched to any reasonable extent; but the returns of these branches should, wherever possible, be returned to the boiler and connected directly and separately into it. To connect the ends of two or more branch circulations into one return, though permissible, is seldom, if ever, so satisfactory as returning each into the boiler.

The cold supply to the one-pipe system of apparatus should be connected into the boiler or into a return near the boiler. If there is a return which runs below the level of the boiler then it should always be connected into this. The great point to be remembered is that when an apparatus is being charged *or recharged*, the incoming water must enter below any point where air can rest or collect. The incoming water must lift all existing water (left in dips or low pipes), and all air, before it. The reader will find full details of the methods and rules to be observed in running the cold supply to a hot-water apparatus, also sizes of cisterns and pipes, on perusing pages 43 to 49. All particulars are afforded there, particulars which apply to all systems of low pressure work.

An emptying cock must be put to every boiler, and particulars relating to this are given on page 49.

For particulars as to suitable positions for expansion pipes, see p. 42 and those following.

* It should be mentioned that the work did not run directly to right and left as shown, but the pipes are straightened out on the illustration to make it clear. The levels are correct.

Sizes of Main Pipes.

One-Pipe System of Apparatus.

Sizes of Mains.	Will carry this radiating surface.
1¼ inch	75 square feet.
1½ "	140 "
2 "	270 "
2½ "	480 "
3 "	750 "
4 "	1300 "

Note.—All circulating pipes must be counted as radiating surface if they are not covered.

Vertical mains, or vertical branch mains, will carry more radiation, therefore a size less pipe may be used for these; thus, 480 feet of radiation may be put on a 2-in. vertical circulation, and at no time is it well to have vertical branches fully large in proportion to the horizontal mains.

Radiator Branches and Connections.

Size of pipe and stop-valve.	Heating surface oi Radiator.
¾ inch	up to 20 feet.
1 "	20 " 48 "
1¼ "	48 " 80 "
1½ "	above 80 "

Note.—It is assumed that radiator branches do not extend horizontally for a greater distance than from 8 feet to 15 feet, according to the size of pipe. When the horizontal distance is greater, a size larger pipe should be used.

The One-Pipe System, with Duplicate and Graduated Mains.

To the best of belief this system has no shorter title, and is but little practised as yet. The scheme of piping is really a combination of the one-pipe and two-pipe systems; for, while there can be no short circuit, there is a distinct and separate return pipe for the water that comes from the radiators, and the main pipes can be graduated in size.

This combined system, while costing a little more, is at advantage when the rising branches go up to several floors, and their returns bring down a considerable volume of water that is cooler than is usually returned into a one-pipe main. With an apparatus as ordinarily constructed the water that passes through a radiator and returns to the main is hot enough to do further service, or, in any case, it is not cool enough to seriously prejudice the temperature of the hot water the main carries; but when the return water is expected to be cool enough to be useless this duplicate arrangement of mains offers an advantage.

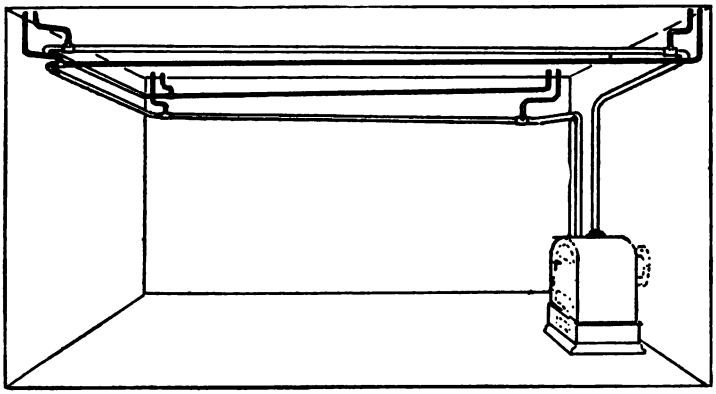


FIG. 40.

Fig. 40 illustrates the piping of mains as might be carried round a basement, the branches rising to supply the radiators on the floors above. The flow pipe starts out from the top of the boiler, and proceeds in its full size as far as the first branch. As this branch takes a fair proportion of the work, the flow is reduced when the branch is passed, and until the next branch of importance is reached. As this is passed a further reduction occurs, and so it proceeds, exactly the same as with the two-pipe system (see p. 66); but with the flow pipe the similarity ends.

The return pipe may be said to commence at the first flow branch, the return of which is the commencement of the

main return, and, on its proceeding, and taking in the next branch return, its size is increased accordingly. This is continued, the return following the line of the flow, but the return increases in size as the flow decreases, the reason for which can be plainly seen. Ultimately the return ends in the boiler in the same size as the flow ; and the pipes at the boiler, both in size and detail of connection, are the same as with any other system.

A peculiar detail in an apparatus erected in this manner is that the main pipes do not both preserve the same line. As is known, the flow pipe has to be given a rise from the boiler, while the return is given a fall towards the boiler—or, it might be said that both pipes rise from the boiler. It is equally correct with this apparatus; but the unusual or opposite paths pursued by the pipes makes them diverge, or open out, as the illustration shows.

Details of sizes of mains and branches, cold supply and expansion pipes, would be the same as with the systems already explained.

CHAPTER VII.

FURTHER EXAMPLES OF LOW-PRESSURE HOT-WATER HEATING APPARATUS FOR BRICK BUILDINGS.

THE OVERHEAD SYSTEM AND METHODS OF WORK TO SUIT SPECIAL CONDITIONS.

THE meaning of the term brick buildings, used in the title of this chapter, is given at the beginning of Chapter V., on page 52, in which the two-pipe system of apparatus is described. For the general elementary details of a hot-water apparatus, of any kind, see Chapter IV., page 37.

THE OVERHEAD SYSTEM of apparatus is really a one-pipe system, but in which almost all the piping is vertical.

Fig. 41 is an outline of an apparatus which may be supposed to be heating several floors of an apartment building (flats), or a warehouse, or block of offices. One building, the writer heated by this plan, was a furnishing establishment of four floors, the floors being constructed of iron and concrete, and no horizontal pipes were to be visible at floor or ceiling lines. The importance of this detail appears when it is stated that the boiler had to be on a level with the ground floor, where the chief show rooms and offices were, so that the usual horizontal mains around the building just above the boiler were quite impossible.

It will be seen that in this apparatus the flow-pipe proceeds unbranched and by the most direct route to the top or a high part of the building. At this point it runs horizontally, perhaps as a single pipe, though more probably it is branched in different directions, until it can descend down the

angles, or other convenient parts, of the rooms below.* The high horizontal part of the flow main must run along a floor or a ceiling, but it may be assumed that on a fourth floor this will be allowed, even if it has to be encased. Failing this, however, it must be run in the roof, and well covered to prevent loss of heat. If it is run along the floor line of the highest floor that is to have radiators, then the radiators may

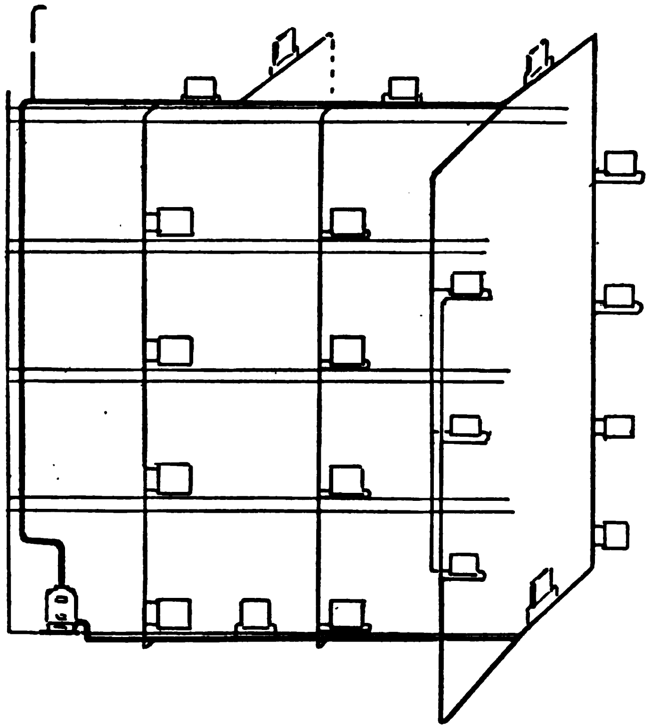


FIG. 41.

be connected to it as shown. In the same way the horizontal main return, which is shown carried beneath the floor line of the ground floor, can, and would, have radiators on it to heat the ground floor.

* The descending pipes in the angles of the rooms are probably inconspicuous, or they may be encased. The main flow-pipe should be cased and well packed to prevent loss of heat, as this pipe carries the hottest water and can lose heat the fastest.

All the descending branches (they might be called branch mains) have the radiators connected on the one-pipe system—that is, the two branches to each radiator proceed from the same pipe, and the radiators may have two bottom connections, or one top and one bottom, as may appear best. Some of each are shown in the illustration. One branch main, however, is shown partly in duplicate—that is, it has an extra pipe for part of its length, this pipe being in the nature of a return to receive the water after it has passed through the radiators, thus keeping the cooled water from coming into the branch main, which is carrying the hot. The illustration makes the connections clear, which, in themselves, are like those described with the special apparatus shown on page 79, and the same result is obtained. It is a plan, however, which is seldom or ever necessary with the apparatus now under discussion, and it is only described because some engineers favour the practice.

Of course, when the main is branched in several places, as illustrated, it can be graduated in size according to the work it has to carry, but should the main circulation by any chance be unbranched, then it must remain the same size of pipe throughout. In this respect it exactly resembles the ordinary one-pipe system (see page 69).

It is claimed for this system of apparatus that, with ordinary care, it never fails to work well and uniformly. Theoretically it is a perfect arrangement, as the flow main carries no work, and is filled with the hottest and lightest water at all times. The returns, which carry cooler water, are all descending pipes and nearly all vertical, and under these conditions there can be no doubt the circulatory movement is the freest and swiftest of any apparatus. On this account the mains and branch mains can be of the least size, and if the sizes given for one-pipe work (page 78) are referred to, and the note beneath the table of sizes (explaining that one less size may be used for vertical pipe) worked to, excellent results will be assured.

Opposed, however, to the advantage of uniform working is the fact that the radiators on the lower floors are of a little

less temperature than those on the top floor, and as a general rule the reverse of this is required. In the first place, a building that is warmed nearly always has heat gather towards its upper floors. This is so recognised that if a fourth floor was as important a place, and required the same warmth as a ground floor, it would not be necessary to put quite as much radiation up there. In the second place it is very unusual for a top floor to be needed as warm as a lower floor; it is generally the least important part of a building, though requiring some warmth to keep stock in good condition or some similar purpose.

This need not, however, be considered a serious fault of the system, but provision must be made to equalise results. It should be noted (1), that it is important that the mains and branch (descending) mains be well covered, so that all possible waste of heat be prevented, remembering that the lower floor radiators are the last to be served. (2) The radiators of the upper floors must be of minimum size for the work and the valves must be carefully regulated (closed), so as to give them only the water they actually need. Valves with loose keys might well be used here. (3) The radiators on the lower floors must be of full size for the work to allow for their slightly lessened temperature, and the best heat nearly always being needed here.

A small example of an overhead system of apparatus is given in Fig. 38, page 75, and may be referred to. It was included in the chapter describing the one-pipe system, owing to its being confined to one floor of a building.

The cold supply to this apparatus would be run in the manner described on page 43, and following pages. The sizes of pipes and cisterns and all particulars are afforded there.

An emptying cock must be put to every boiler, and particulars relating to this are given on page 49.

For particulars as to positions for expansion pipes see page 42.

Sizes of main pipes and branches are the same as with the one-pipe system, page 78, observing the note relating to vertical mains which follows the table of sizes.

WARMING BY HOT-WATER PIPES OR RADIATORS *FIXED OVERHEAD.*

For some little time past a method of warming has come into practice which would appear to upset the general ideas as to how pipes or radiators afford heat, until it is remembered that a circulation of air must occur when a hot body is placed in a room, whether the body be high or low or midway. It must be said, however, that with the heated surfaces as near the floor as possible the best results are obtained, and the quickest, but with several jobs inspected and tested the overhead heating surface has done excellent work; perfect work it might be said.

One job in particular was a tobacco factory, and all floors were heated by lines of pipe carried about 3 feet from the ceiling and about 9 feet from the floor. Taking a typical floor of the building, this was about 80 feet long by 40 feet wide, and was occupied by about 150 to 180 girls making cigars. These girls, also the forewomen, who had not the slightest interest in speaking favourably of the heating apparatus, and who would have been ready enough to grumble if complaint could be made, said they were quite comfortable. When asked if they experienced more heat at their heads than their feet, they said no in such a way that it could be seen that no discomfort or unusual feeling whatever had been experienced. There was no heating surface at the floor line, and although the pipes near one ceiling would afford warmth to the substance of the floor above, very little could be expected to go through, as the floors were of iron joist and concrete construction.

This method of work is particularly suited for factories and similar places, in which an extensive area has to be warmed; probably too extensive for pipes or radiators on the floors, against the walls, to deal with. Furthermore, in the majority of factories the walls are utilised either for benches, machine tools, or other purposes. In very few such places is it the custom or wish to leave the walls unoccupied. If a factory

consists of two or more floors, the light is obtained through windows around the side walls, in which case there are always benches or machines along the walls where the best or more delicate work requiring the best light is done. Even in single floor (bungalow) factories, with the light coming through sashes in the north side of each roof ridge, the walls are almost invariably occupied.

Taking for granted that the walls are practically never available for pipes or radiators, where can they be put? Any attempt to place them on the floor nearer the middle of the factory is quite out of the question, and the overhead pipe comes as a solution to the problem.

Fig. 42 will give an idea of how such a job might

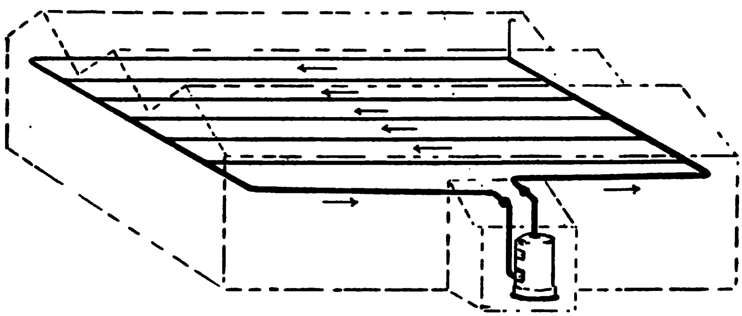


FIG. 42.

appear. The faint outline suggests a factory (a printing works, for instance) wholly on the ground level, and lighted by north lights in the ridges of the roof. The boiler is supposed to be in a small outhouse, and the thick lines show a main flow pipe proceeding from the boiler to one end of the building and along the wall there. From this flow a number of 2-in., 2½-in., or 3-in. pipes run the whole length of the place, descending as returns, and join a main return at the opposite end, whence it proceeds home to the boiler.

It must be admitted that, as yet, the writer has not seen a job of this kind done with low-pressure hot-water. It has always been either steam or high-pressure hot-water, but there is not the least reason why low-pressure hot-water should not

be used. It is as economical, and, assuming the fire is kept alight night and day as usual, the heat will be as positive and regular as with any mode of heating, perhaps more so, and it will not freeze.

The general principles to be followed in this work are the same as with the ordinary one-pipe or two-pipe systems, according to which appears to be best to meet the conditions; and the sizes of mains and other details would remain the same.

Church Heating.

There are two things which may be counted as difficulties when heating places of worship or public buildings of large area and lofty interiors. One is the down currents of cold air that are usually experienced (in cold weather); the other being the impossibility, more or less, of getting the heating surface distributed so as to give the best results.

Taking the latter difficulty first, the average church appears to be planned by an architect who has a disregard for the heating arrangements. Pews are carried to the walls on both sides (even under the windows, where a downward movement of cold air is sure to occur in cold weather), and the boiler pit is put anywhere. It would be far better if the seating accommodation could be arranged so as to leave the side walls clear, where pipes and radiators could come above the floor. The more customary plan, made necessary by the arrangement of seats, is to have pipes in trenches with gratings over, and, remembering that they are usually 4-inch pipes, nothing worse could possibly be devised.

The large pipes, 4-inch, hold so much water that of all heating arrangements they are the slowest to get hot and the slowest to cool. Both are good features in horticultural works, as may be learned by turning to that section of this book, but while the slow cooling is no gain in a church, the slowness in heating up is a distinct fault. If low-pressure heating is adopted, every effort should be made to use radiators, with the smallest main pipes that will do the work

well, as, by keeping down the bulk of water in an apparatus, the quickest heating is assured. It is the fact of a church (or public place) not being heated every day, with the fire constantly alight, that makes quick heating essential. In one case heard of, the fire of a church heating apparatus had to be lighted on Friday evening to afford sufficient warmth for Sunday morning service. If the consumption of fuel was proportionate to the time, the extravagance was enormous.

Every effort should be made to erect an apparatus that will heat up quickly, and to do this to best advantage the whole of the radiating surface should be above the floor and uncovered. Four-inch pipes should be avoided, and if pipes must be used (as radiating surface), let them be 3-inch and 2-inch. A 2-inch pipe has half the surface of a 4-inch one, but it holds only one-fourth the water. In the ordinary way an apparatus is made up almost wholly of 4-inch pipe, mostly in grated trenches, with some built up in coils and covered with coil cases. Supposing the apparatus to be quite new, the loss of heat due to trenches is at least one-fifth, but after a few months or a year the loss of heat is far greater. The passage of numbers of people over the trench gratings, the dusting and cleaning of the place, and other things, literally load the trench pipes with dirt; in fact, they are sometimes found to be loaded on top and half buried beneath with dust and what is termed "flue"; and the coils in the coil cases are little better. Now, remembering that this dirt is composed almost wholly of poor conductors of heat—hair, fibre, cotton, wool, grit (silica), etc., the loss of heat, or rather the prevention of heat emission, is equivalent to wrapping the pipes in a blanket. It must not be thought that church attendants clean the pipes, for it is beyond their power. There may be a ton or more of gratings to be removed, and by the time the dirt was got away and the pipes well cleaned, the rest of the church would be in a terrible state.

Briefly stated, use every means to get the heating surface above the floor. Put radiators (or pipes) along the walls, get radiators against the risers of the front and back pews, and against the chancel and the transept walls. Make a special

effort to heat all lobbies and entrance ways as, notwithstanding the ventilating arrangements, these places are usually the source of insupportable draughts.

The other difficulty referred to is that of the down-currents of cold air. Let it first be explained that this has nothing to do with the downfall of cold air at the windows. The latter, if it has to be treated, must be considered separately; but the best plan, if it lies in the engineer's power, is to persuade the architect to keep seats away from the windows.

The downward movement of cold air, commonly felt over the whole body of a church, or nearly so, is due to the height of the place. Reliable experiments have shown that the heat —heated air really—from pipes or radiators placed on or near the floor has little or no effect in warming the air above 15 feet height. At about this height the heated current turns in a lateral direction and presently descends, and in doing so is either cooled by the upper stratum of air, or brings some down with it. This unpleasant effect is doubtless made worse by the common use of inlet ventilators of the Tobin-tube pattern, which discharge cold air a few feet over the heads of the congregation, but it is a fact that the cold downward movement of air referred to occurs when the Tobin's tubes are either closed or do not exist.

Some very reliable experiments relating to the action of warm air currents were made which have an important bearing on this subject, for they showed that in high interiors, as stated, the heated air rising from pipes or radiators near or on the floor did not ascend beyond about 15 feet height. The outcome of this is to show that to deal with the upper air of churches there should be another set of pipes or radiators at just about the 15 feet level, or a little above it. This has been done as far as is possible, and has proved a success, so much so that our best engineers, when designing this work, always arrange for one or two pipes to come around the wall at about the height named, or as near to it as possible.

In one instance, of the writer's experience, not only was the customary amount of radiation provided at floor level and a pair of pipes also run about 16 feet high, just beneath the

clerestory windows, but an additional four pipes were run along the horizontal beams in the apex of the roof. This made an excellent job, and considering the money spent in erecting churches—which are not a cheap type of building—the comparatively small extra cost of these upper pipes should always be willingly borne. It certainly should be so, remembering that they obviate an unpleasantness which is little short of a danger to many.

In the instance just recorded, the roof pipes formed a distinct apparatus on the high pressure principle, with its filling cap and expansion pipe in the tower. The chief idea in this was to enable the roof to be heated in summer, if desired, to promote ventilation.

Another mode of dealing with the upper air in high interiors lies in discharging warmed air there. A large coil or battery of 1¼-inch low-pressure, or ⅞-inch high-pressure, pipe is made, and suitably connected up for heating, and through this a supply of fresh air is propelled by a fan or blower. This affords the needed warmth to the air, which is then carried by tubes or ducts, and discharged through openings, around the church interior walls, at a suitable height. This quite defeats any down currents of cool air that might set in in cold weather. The chief objection is the primary cost; but it can be run quite economically when once the arrangement is installed, and could be used for ventilating purposes without heat in the summer.

In any case, it is highly desirable, in church work, that no inlet ventilators of the Tobin's tube design exist to bring in and discharge air above the heads of the congregation, unless provision is made for warming the air in winter. This is sometimes done by putting two or three small radiator sections in the base of each air tube, the tube being specially made for the purpose. By this plan sufficient ventilation can be obtained for cold weather without any disagreeable effects; but to send cold air, at from 12 to 16 points, at about a 7 feet or 8 feet level, into a building warmed by hot-water is—well, unreasonable.

An ever present weakness in a low-pressure hot-water

apparatus, when installed in a church, is the liability of its water freezing at some point or points in very cold weather, when the fire is not alight. Certain churches have services three or four times a week, and can afford to keep a fire in the boiler the whole of the winter season ; but a great number, probably the majority, have no heat for three or four consecutive days each week, and unless great care is used and the conditions are favourable, a severe frost may prove destructive. On this account the apparatus that is being somewhat favoured for this and similar purposes is that of the high-pressure principle, the reason being that the pipes of this can be charged with a non-freezing solution. This makes all parts frost-proof, but, in addition to this, a high-pressure apparatus, if properly erected, is quicker in heating up than one on any low-pressure system ; and, again, a high-pressure installation will, as a rule, be found to be the cheapest to erect. Unfortunately, the London Building Act, which most surveyors and authorities recognise, will not allow a high-pressure pipe to be run nearer than 3 inches to wood-work or any inflammable material, but this and all details relating to the high-pressure system will be found in a later chapter of this book.

CHAPTER VIII.

EXAMPLES OF LOW-PRESSURE HOT-WATER HEATING APPARATUS FOR GLASS-HOUSES AND HORTICULTURAL BUILDINGS.

FOR the general elementary description and details of a hot-water heating apparatus, the reader is referred to Chapter IV., page 37.

In glass-house work it will be found that the radiator seldom appears (unless it be in a conservatory or winter garden), while the 4-inch pipe, or at the smallest the 3-inch pipe, is the favoured radiating surface. Probably cheapness may be a factor in this, also the ease with which almost unskilled men can do the work in the ranges of houses used by market growers; but an important feature with the 4-inch pipe is that it holds more water for a given surface than any heat radiating medium that is generally used. Besides this, rows of pipe give a more uniform and well distributed heat in a building that is composed, almost every inch of it, of heat losing material—glass.

The advantage of a good bulk of water in a horticultural apparatus is that it does not readily show any neglect or variation in the stoking. It is slow to heat and slow to cool, both advantageous, for once the place is got to the required warmth, the gardener or grower does not want the temperature rising and falling, even one degree, every time the furnace is attended to, or wants attending to, or is neglected a little.

Horticultural glass-houses may be said to be of two kinds, viz. those which are built against a wall and would be called "lean-to," and those that rise to a ridge in the middle, both sides of which are alike (not being bounded by a high wall), and are called "span" houses. With a lean-to house it is

sufficient to run the pipes along the side furthest from the back wall, and this gives quite satisfactory results. The wall side requires no pipes, unless it should be a tropical house, or "stove," for forcing, etc., in which case pipes are put wherever they can be got as the quantity is considerable. In span houses (which might be said to resemble two lean-to houses leaning or standing against one another) the pipes are run on both sides and, when necessary, pipes may be carried around the ends and up the centre also.

The reason for this arrangement of the pipes is that the glass is the heat losing material, compared to which brick-walls may be considered quite heat-proof. In calculating the length of pipe required to afford a certain amount of heat in this work, the glass measurement only is taken, all brick and woodwork being ignored as taking no part in the heat-loss which has to be constantly made good. This is referred to fully in the chapter on QUANTITIES which deals with the heating surface required to afford certain temperatures.

Let it be explained here that it is the exception and not the rule for the heating engineer to dispose the pipes, that is, to say where they had best, or shall, be run. The gardener settles this, and much more, and if the engineer does not at first realise that the gardener has a ruling voice in this work, he doubtless will soon be made to know it. Practically every residence or place requiring glass-houses, even on a moderate scale, has a regular gardener, and he must be considered in every possible way.

The most simple form of apparatus we have for heating glass-houses, yet about the most ingenious, is that in which the boiler is built in the thickness of the low brickwork at one end of the greenhouse, and which, therefore, requires no pit nor house to accommodate it. It has the further advantage of requiring no connecting pipes between the boiler and those which heat the house, for the back of the boiler comes inside the house, and the heating pipes proceed direct from it. Again, the water-supply detail is greatly simplified, for the feed tank forms a syphon-end for the pipes, also a support to them and an air vent at the same time.

Figs. 43 and 44* show such an apparatus, the first showing the detail of parts, the second showing it fixed in position for heating a small lean-to house. It will be noticed that the fixing is of the most simple description, the boiler being either

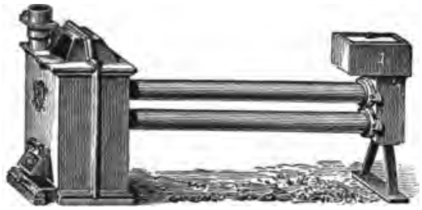


FIG. 43.

built in as the dwarf wall is made, or a suitable hole is cut and the boiler placed in and cemented round. This boiler has no water-way at the front but is lined with fire-brick there, so that if rain or snow beat upon it the heat of the apparatus is

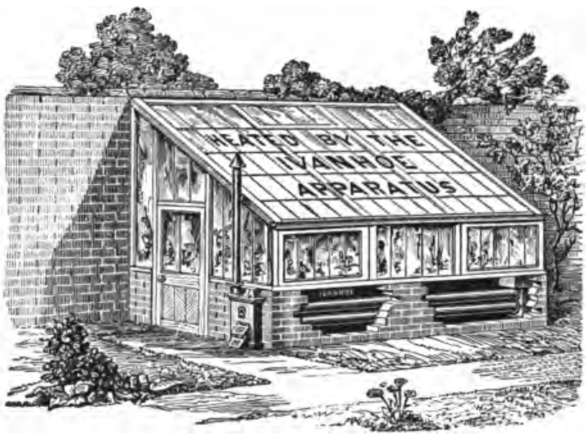


FIG. 44.

not reduced and no harm is done. All stoking and attention is done outside, so that the door of the house need not be opened, nor is any dust made within.

This apparatus, in some similar form, appears in most

* The "Ivanhoe," by R. Jenkins & Co., Rotherham.

catalogues, and is sold complete with a simple kind of rubber collar joint for the pipes, so that amateurs may erect it complete if they so desire. The cistern would be hand fed and need not have a ball-valve.

Fig. 45 shows a method that could be adopted for warming two adjoining houses, without the use of the mains which appear in the next example. It may be supposed that one is a hot house, while the other larger one is for vines or general purposes, and would be ten or fifteen degrees cooler. Only the flow pipes, that is the top pipes, are shown, this being a plan drawing, but it can be easily understood that the return pipes would be exactly the same, but beneath the flows. The valves in the positions shown admit of the two houses

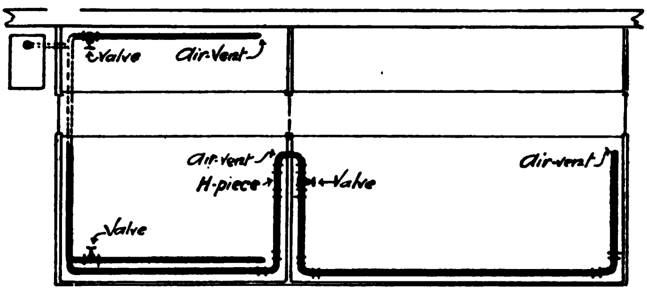


FIG. 45.

having their heat regulated independently. This is very necessary as will be understood, yet very commonly neglected. At the point marked, or thereabouts, an H piece would have to be inserted to admit of a return circulation occurring there when the valve in the larger house should be closed. Air pipes would be needed at the points marked, these being highest points of circulation, while one is on the boiler side of the valve in the larger house. The valves being for regulating the heat need only be in the flow pipes, there need not be any in the returns. The dotted piece of circulation near the boiler is kept just beneath the ground level until it has passed the doorway and path.

The cold supply to this apparatus might be by a cistern

forming a syphon-end to the circulation in the larger house, the same as that shown with the small example Fig. 43, but it is more usual to put a cistern as near the boiler as possible and let the supply pipe enter a return pipe, near the boiler, with a small dip, as Fig. 46. The cistern need only be just above the level of the highest part of the circulating pipes, and is thus convenient for inspection and replenishing, as practically all horticultural heating apparatus are hand-fed. It is as well to let the cistern have a lid, otherwise dust and vegetable débris will get in. There is generally quite enough of this in the water that the apparatus is fed with* without adding any from other sources. For further particulars relating to cold supply services the reader is recommended to refer to page 43, and the pages following it.

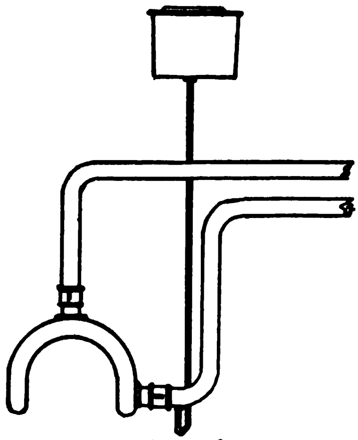


FIG. 46.

The air pipes from this and all horticultural heating apparatus are usually of ¼-in. or ⅜-in. size (internal diameter), and while some use composition piping for these it is better to use iron or copper.† The important thing to remember is that air pipes must be run with a rise, all the way from the pipe they are connected to, to their upper extremities, and no part of them containing water must go outside the house where frost can attack them. The reason for the rise given to these pipes is that at no point must the air be expected to go *downwards through water.* If there is a dip in the part of the pipe that is below water level, no air will get through it. If there is a dip in the pipe above water level, it is highly

* Gardeners are often very careless regarding this, pipes sometimes being found half filled with mud, while many boilers are destroyed by dirt accumulating in the lowest part of the waterway.

† Thin copper tube does not come so expensive as it may sound, while it is everlasting and is not so easily injured as compo pipe.

probable that a little water will get into this, through some cause, and this will act as a barrier to the free escape of air. An air pipe must not descend at any point, nor should it be quite horizontal.

Fig. 47 is an example apparatus such as might appear in a range of five glass-houses, with melon pits in front. Only the flow, i.e. the top pipes, are shown, this being a plan drawing; the returns would be immediately beneath them. The circular marks in the pipes represent the positions of the stop valves, but these would be in the flow pipes only, not the returns.

This illustration introduces the mains that have sometimes to appear in this work. It is hopeless attempting to heat several houses in a line, giving independent regulation to each, yet letting the pipes continue from house to house without mains. As a rule the mains are made use of to heat melon and cucumber pits, which are built along the fronts of the houses, and as these have moveable lights the heat in them can be

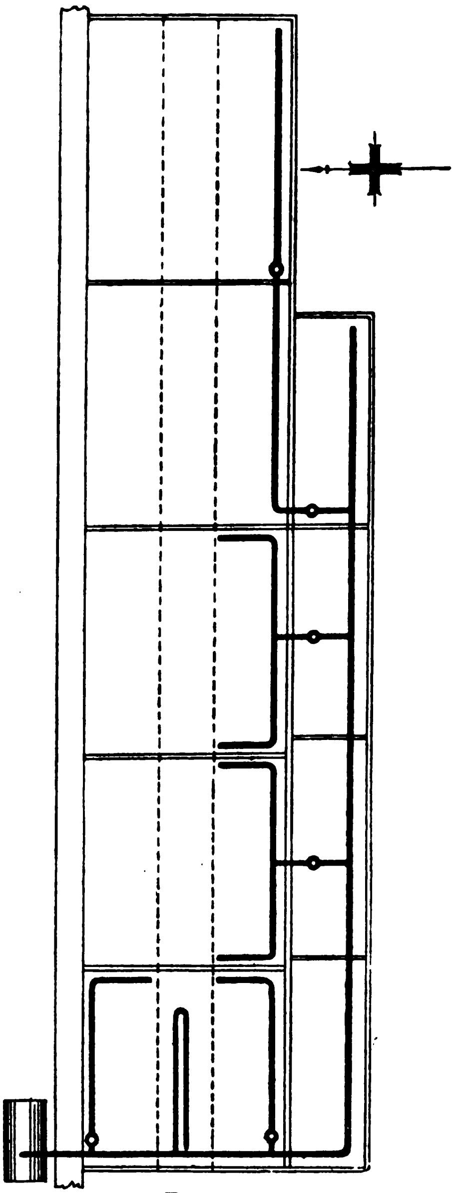


FIG. 47.

regulated without interfering with that in the pipes; or a piece of matting is laid over part of the pipes to reduce the heat. If the mains are not carried along through melon pits, they may be carried beneath the floor level; or they can in some cases be carried along the other side of the wall the houses lean against. It may be that on the other side there is a gun-room, stores, etc., that will benefit by the warmth.

This illustration needs no further description except to say that the mains are beneath the floor line, where they cross the house from the boiler to the melon pits, and the branch circulation up the path could be under a grating or alongside a bed. Details of cold supply, air-pipes, etc., were given with the example preceding this.

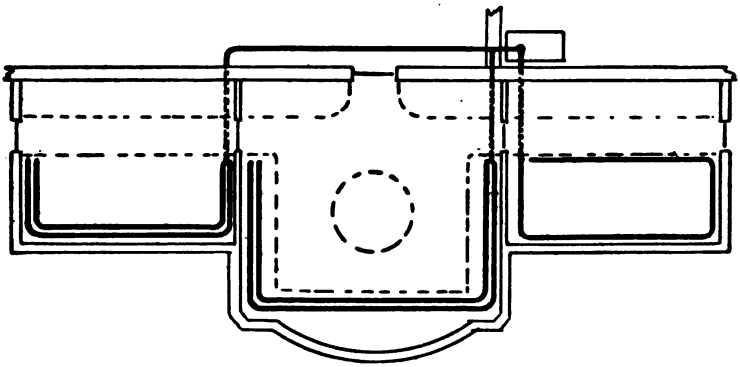


FIG. 48.

In Fig. 48 is given an example of work as might appear in some well-built houses in the grounds of a large residence. The centre house would, perhaps, have a domed roof for palms, and would possibly be used as a winter garden. The two side houses might be an early and a late vinery. In the vineries the pipes would be around the beds, but in the centre house the pipes would be hidden beneath the stagings.

In disposing hot-water pipes, if the engineer should do this in the absence of a gardener, the common practice in what may be termed the ordinary type of lean-to greenhouse, is to carry them along the dwarf wall beneath the lowest part of

the roof, while with a span house they occupy a similar position on each side, beneath the two lowest edges of the roof. This has been explained already, and a different arrangement can be shown in Fig. 49, which represents the piping as usually done in tomato and cucumber houses and in vineries. In these there is no staging, and the plants are rooted directly into the earth, which forms the floor of the house. For very early produce a pair of pipes may be needed, as shown in the

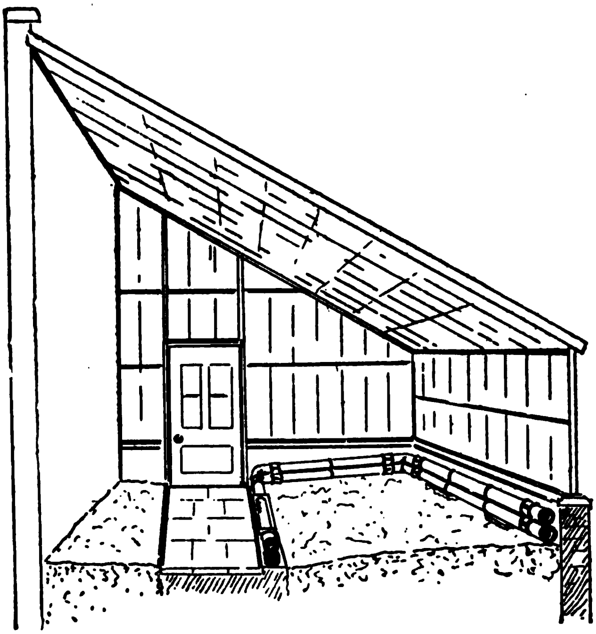


FIG. 49.

illustration, but for a little later use or market one pipe only is used. On the upper pipe alongside the path a trough is shown. This, when filled with water, gives off vapour and makes the air humid, as required in certain stages of growth with various plants.

Tomato and cucumber growing for the early market is now a great industry, and for this purpose rows of low span houses, placed side by side, are used. In these a somewhat ingenious plan for getting a uniform temperature is adopted

by having an open division between each house, and carrying one or two pipes there. Fig. 50 will give an idea of this. It is a cross section, or end view, of some houses, and between each is a valley gutter, as shown, and as is necessary. This gutter is supported by light brick piers, coming about every 8 feet, and which the pipes shown either pass through or run alongside of. There are also pipes each side of the paths, as indicated.

The details of a well-equipped forcing house appear in Messenger & Co.'s (Loughborough) Catalogue, and the illustration is reproduced here, Fig. 51. This shows a bed on one side, with bottom heat, and a pipe around its upper edge, while on the other side is a stage with pipes beneath.

Referring to the provision of bottom heat to beds, it is

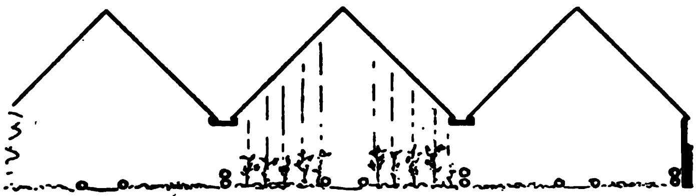


FIG. 50.

often required that an independent bed, or pit, be built in a glass-house, and Fig. 52 shows the customary method of providing the heat. Pipes are carried along lying on the bottom of the bed and over these clinker and rough material is spread. Above this is some finer stuff and on top comes the earth. The rough material allows of the heat circulating throughout the bottom of the bed, and answers well in this respect. Occasionally the bottom of the bed is well perforated, and rough stuff put in, as described, but the pipes are within the low enclosed space beneath the bed. The gardener probably settles this question.

For what the information may be worth, it may be stated that an American author says* that, in his country, the 4-inch pipe is being discarded in favour of smaller wrought-iron

* In the "Plumbers' Trade Journal" (New York).

tube for glass-houses, though the reason for this is not given. And he goes on to show how the heating is done, which is more interesting, and is reproduced here. Fig. 53 illustrates a cross section (or end view) of a span house; while Fig. 54 is a perspective view of one half of the piping. In the first illustration there is what appears to be a division shown in the centre of the house, but in reality it is only a series of posts or standards to support the ridge, that comes here. In

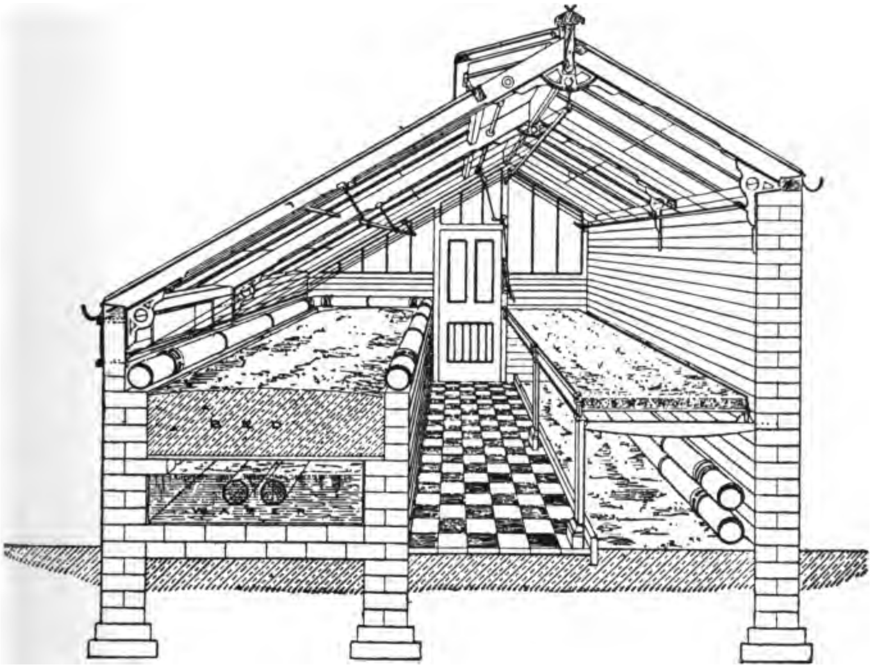


FIG. 51.

any case, however, the piping is divided into two sections, there being two overhead flow pipes, these descending and coming home as two sets of radiating pipes, heating two beds each, but running close beneath them. There is, of course, no special need for pipes to be near the floor, if all the propagating is done in beds about two feet off the ground, and the scheme of piping shown may prove as good as any. The

writer would, however, have liked to see a small space between the outer beds and the outer walls, so as to let warm air work up between these beds and the glass. It is difficult, too, to see why so many stop valves are used, and unless the flow pipe falls on its way through the house it would require an air pipe on the high point where it drops to the radiating pipes. Apparently these latter pipes are given a rise towards the boiler, as air vents are shown at the ends nearest the boiler, and this is contrary to our practice, though it probably works satisfactorily.

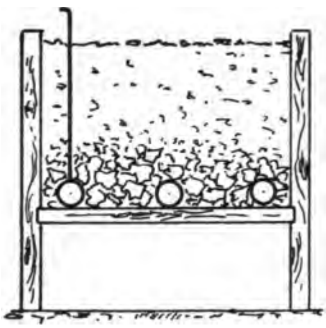


FIG. 52.

An interesting lesson that the example affords is, that of constructing an apparatus that could be worked from a boiler fixed on the same floor level as that of the glass-house. This was not the case in the instance now illustrated; but it sometimes transpires that such an arrangement would be advantageous. If the radiating pipes were run near the floor,

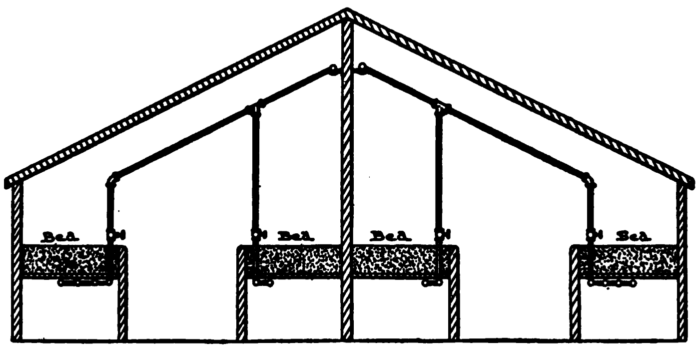


FIG. 53.

according to English practice, or as is required with, say, tomato beds, then the boiler (the ash-pit really) might be sunk a few inches to allow the returns to enter without rising to it.

In regard to the sizes of main pipes and branches in horticultural work, the table given for two-pipe work, on p. 65, could be referred to, but the fact is a table for mains is seldom or ever required in this work. In all works but the smallest the radiating pipes are of 4-inch size, and as the boiler is kept close to the work the pipes coming from it are 4 inches also. The limit of work that should be put on a

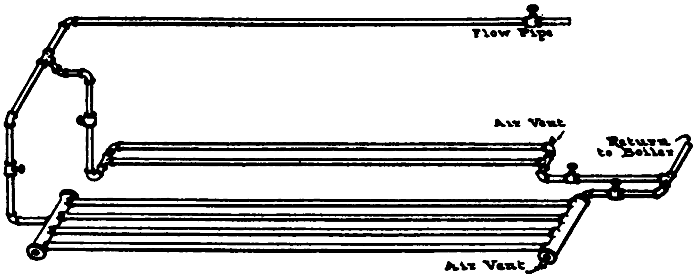


FIG. 54.

pair of 4-inch mains is about 1000 to 1100 lineal feet, and if a job contained more radiating pipe than this it would be necessary to use larger mains, provided that only one pair of mains could be used. As a rule, in large works, the boiler is so situated that two or more pairs of mains have to be, or can be, used, therefore the 4-inch pipe nearly always remains large enough.

CHAPTER IX.

QUANTITIES:

BEING THE AMOUNT OF HEATING SURFACE REQUIRED TO AFFORD CERTAIN TEMPERATURES.

LET it be first stated that although the quantities for warming brick buildings and those for glass-houses are both dealt with in this chapter, they have to be treated from quite a different standpoint, as a rule, for one cannot be made to answer for the other. The warming of brick buildings is, therefore, dealt with first, as being the more difficult subject of the two.

QUANTITIES FOR BRICK BUILDINGS.

There are many different, almost conflicting, conditions experienced in brick buildings, all of which would need to be considered, if precise results were aimed at; and it is highly probable that the results would not be perfect, even then. It is a simple matter to say that a radiator, at a certain temperature, gives off so many heat units per hour, and that a given volume of air requires so many units to raise it to a certain temperature. It is not requisite to go into this here, for it is not reliable. It will be found worked out on p. 18, where the heat unit is described. In Germany this mode of calculation has some favour, but, of course, they make necessary allowances for the cooling influences, for it is these which prove the calculations wrong. In the first place, there are the changes of air per hour; then the loss from glass windows,

which is the greatest heat losing surface we have in buildings of practically any kind.* Then there is loss from walls and ceilings, and in the country named there are tables giving allowances for walls of different aspect, exposure, and different thickness, also ceilings (floors) of different thickness and material. As yet there are no indications that such a method of calculation would find favour—or general use, in England.

There is no reason why the area of glass should not be taken into consideration when calculating quantities, and some thought should be given to the area of outer exposed walls. A rule that works well in this way is as follows:

Rule.—To obtain 60° in any ordinary brick-built room when it is 30° outside:—

Allow 1 square foot of heating surface to each 5 square feet of glass, with the addition of 12 square feet of heating surface to each 1000 cubic feet of space in the room. Add 10 per cent. to the latter, if the room has two exposed walls.

The most generally liked table is even more simple than the preceding rule, and allows for rapid calculations with less measurements, but it makes no allowance for varying conditions such as a greater or less glass area, etc. The writer must confess to using it frequently, but it is with an experience that admits of any unusual condition being immediately seen, and noted, when the place or plans are inspected, and subsequently allowed for. The table is shown on next page.

For living rooms and occupied places add 10 per cent. for each exposed wall more than one. Add also one square foot of heating surface for each five square feet of window area that appears to be above the normal for the size of room or place. See p. 89 for calculating cubic contents of churches and high interiors.

Pipes in trenches, as in church work, should be calculated as being of 15 to 20 per cent. less effectiveness than pipes above the floor.

* It is usually calculated that sheet iron loses heat as fast as glass, and a building of galvanised corrugated sheet iron, if unlined, would have to be treated much as a glass-house.

TABLE.

HEATING SURFACE required to afford certain temperatures in brick buildings when it is 30° outside; based on cubical contents only, but allowing for a normal, i.e. usual, area of glass in windows.

Temperature required.	Square feet of heating surface required for every 1000 c. ft. capacity.	Some of the purposes to which the rooms or places may be put.
° Fahr. 50	9	Coach houses, stores, etc.
55	11½	Churches (when empty), workshops, factories, sleeping apartments.
60	14½	Living rooms, banks, offices, shops, etc.
62	16	
65	18	Living rooms.
70	22	Bath rooms. Also to afford 60° to 62° in entrance halls and lobbies.
75	29	Drying rooms for various manufacturing and commercial purposes.
80	38	
85	50	
90	66	
95	87	
100	115	Drying rooms for laundries, and as required for many wet substances in various trades. These high temperatures are only attained when the room is empty, or the goods are dry.
110	195	
120	295	

These tables are based on the assumption that in the coldest weather the water in the radiators is from 175° to 185° F.; while for the higher temperatures, for drying rooms, the water would require to be from 200° to 205° F.

QUANTITIES FOR HORTICULTURAL BUILDINGS.

In calculating the heating surface required to heat a glass-house it has never seemed necessary to the writer to make any allowance for loss of heat from walls. There certainly is a dwarf wall around the customary three or four sides, according to whether it is a lean-to or a span house, and there is of course the back wall of the former kind of house. But when the figures for the glass are got out, the allowance for loss from walls and for cubic contents, or ventilation, is so trifling that it might reasonably be ignored, though the better plan is to include a small percentage in the general calculations, remembering that the wall area is a mean average in practically all horticultural buildings.

The glass of these buildings is partly vertical and partly sloping, but no practical difference occurs in their heat losing qualities. In Hood's original work on warming buildings he devised a rule, based on the fact that a square foot of glass will cool 1¼ cubic foot of air (contained in a glass-house), to the temperature of the outer air, per minute; and although this rule appears to be complicated and has been disparaged by other authors, the writer has failed to find anything that is an improvement upon it. The rule runs as follows:

Rule.—Multiply 125 by the difference between the temperature at which the place is purposed to be kept, when at its maximum, and the temperature of the external air. Then divide this product by the difference between the temperature of the pipes and the proposed temperature of the place. The quotient thus obtained, when multiplied by the number of cubic feet of air to be warmed per minute, and this product by 222, will give the number of feet of 4-inch pipe which will produce the desired effect.

The Table which shortly follows is calculated by this rule, and is based upon there being an average of 240 square feet of glass, per 1000 cubic feet contents, in glass-houses. This, however, is where the Table may err, for it is not possible to find or guess the area of glass a house may have, by its con-

tents. It is, therefore, best to measure up the glass and work it out by the rule given, and it will not be found that this rule is so alarming as it looks. Having obtained the area of glass, the pipe can be found by the rule in less than ten minutes.

In making the following Table, the area of glass allowed—viz. 240 square feet to each 1000 cubic feet capacity, was arrived at as follows: Supposing a lean-to glass-house was 15 feet long, 10 feet wide and 6 feet 8 inches mean height, it would have a capacity of 1000 cubic feet. This house would have a roof 15 feet by 11 feet, a strip of glass in front 15 feet by 2 feet, and two ends of 40 square feet each. These together make 275 square feet, but one-eighth has to be deducted for woodwork, and this reduces the total glass area to 240 square feet.

To show how the rule is worked, let it be supposed that a house is to be kept at 50° Fahr. when it is as low as 20° outside. When this cold temperature is registered outside, it is supposed that the water is kept at 180°.

Therefore:—Multiply 125 by the difference in temperature of internal air (50°) and the outer air (20°), viz. $125 \times 30 = 3750$. Divide this by the difference in the heat of the pipes (180°) and the temperature of the internal air (50°), viz. $3750 \div 130 = 28\frac{11}{13}$. Multiply this by the volume of air to be heated per minute ($240 \times 1\frac{1}{4} = 360$ feet), viz. $22\frac{11}{13} \times 360 = 8654$. Divide this product by 222, viz. $8654 \div 222 = 39$. This latter is the length of 4-inch pipe—39 feet—required to heat the space to 50° when it is 20° outside, the water being then at 180°.

TABLE.

HEATING SURFACE REQUIRED (given in 4-inch pipe) for GLASS-HOUSES, based on their cubic contents. In this table it is calculated that there is 240 square feet of glass to each thousand cubic feet of space, and that the lowest outdoor temperature is 20° Fahr. When the weather is as cold as this, it is supposed that the water will be kept at 180° in the flow pipes.

Temperature required.	Length of 4-inch pipe to each 1000 cubic feet capacity.	Some of the purposes to which the houses may be put.
° Fahr.		
40	22	Trees, cuttings, cool-house.
45	30	Fruit trees, conservatories.
50	39	
55	48	Grapes, tomatoes, cucumbers, strawberries.
60	58	
65	69	
70	81	Tropical house, orchids, some ferns, melon pits.
75	95	
80	111	Pines and forcing purposes.
85	129	
90	150	

To find the length of 3-inch pipe equal to the above, add one-third to any of the quantities; for 2-inch pipe, double them. This is not strictly correct, as the external diameters are 4½ inches, 3½ inches, and 2½ inches respectively, but the error is the right way, and is the usual quick method of arriving at the required result.

CHAPTER X.

TESTING HEATING PLANTS WHEN THE OUTDOOR TEMPERATURE IS ABOVE 32° FAHR.

BEING A PAPER READ BEFORE THE INSTITUTION OF HEATING AND VENTILATING ENGINEERS, BY THE AUTHOR, AND FOR WHICH HE WAS AWARDED THEIR BRONZE MEDAL.

IN practically every case when a heating apparatus is erected, a certain rise in temperature is guaranteed or forms the basis of the order, and in the majority of instances this rise is from 32° to 60° Fahr. Occasionally the figures vary, though not to a great extent, and the conclusions arrived at in this paper will bear variation to meet any reasonable difference in the temperatures.

The engineer, having undertaken to afford a certain rise in temperature, it follows that, on the completion of the work, some sort of test takes place to show that the promised results are obtainable, and it is in this that a very real difficulty arises, for the outdoor temperature is so rarely at 32°, and when it is it cannot be relied on for many hours. Consequently, it is a very remote chance that the appointment to test finds the outdoor air at 32° and, failing some recognised rule or table, the test may amount either to nothing or a dispute. If an apparatus capable of affording a 28° rise of temperature from 32° to 60° would afford a 28° rise from any other outdoor temperature, say from 42° to 70° or 39° to 67°, then everything would be simple and satisfactory; but this is not the case by any means, for, when the outer air is above 32°, the increase that an apparatus can afford falls in a rapidly decreasing ratio. It will be seen from the table suggested that an apparatus capable of affording a 28° rise

from 32° to 60°, can only cause a 14½° rise when the outer air is 56°, and a 2° rise from 32° to 34° finds an equivalent in half a degree rise from 69¼° to 69¾°. The sole purpose of this paper, therefore, is to propose a table that may be worked to with some degree of certainty and satisfaction when the outer air is above 32°, and if any argument of the need of such a table were required, then it can readily be provided by stating that, with some two hundred or more observations made during the past winter, the outdoor temperature was only once found to be 32°, and then for one hour only.

It is necessary to explain that my house is warmed throughout—every room—by hot water, and the apparatus, always tended carefully, was stoked and looked after with particular care during the months the tests were on. Two rooms were chosen (the cooler room an unused bedroom), one with north aspect, on which the sun did not shine; the other with a west aspect, on which the sun never shone until the tests were over—at noon. The morning hours were chosen as being the most reliable, for during the afternoon the results often varied, probably by reason of sunshine or other variable outdoor phenomena. Indoors, too, the phenomena varied by the rooms being used, cooking operations taking place and other variable factors. Each room had what may be considered a normal area of glass, and each had a chimney of equal area and height acting as extract ventilating shafts. Both rooms were about 20 feet from an outer entrance or source of outside air. Every effort, as will be understood, was made to get reliable normal results. On this account the temperatures, on many days, were discarded, or not taken, owing to some happening likely to give abnormal results; such domestic details as cleaning the rooms, etc., making a great difference in the warmth registered. Needless to say, also, the thermometers were carefully tested and all were hung in mid-air in positions where it was considered they would register the general temperature and not that of currents of air. Much more might be said regarding the different precautions taken and the pitfalls avoided, and it is hoped, therefore, that it will be taken for granted that

everything possible was done to ensure reliable working results.

Hitherto the only attempts in this direction have resulted in algebraic formula, unsuited I would submit, for general practice. In a paper read before an American Society the following rule appears :—

"Let T represent the temperature of the steam or hot water in the radiator, t the temperature of the air in the room, and t_0 the temperature of the outside air. Then

$$\frac{T - t}{t - t_0} = k$$

when k is a constant quantity for each building and plant.

"If, as is usually the case,* t is 70° and t_0 is 0°, then the value of k will be

$$k = \frac{T - 70}{70}$$

From these equations we get

$$t = 70 \times \frac{(T - 70)\, t_0}{T}$$

This latter equation enables anyone to determine the temperature, t, which should be maintained inside a building when the temperature outside, t_0, is higher than 0° (zero), and when the heat of the water or steam is T."

Professor Carpenter (of the Cornell University, U.S.A.) gives the following formula :—

"Let T be the temperature of the radiator, t' that of the room and t that of the outside air for the conditions corresponding to the guarantee. Let B equal loss from room for 1 degree difference of temperature ; let c equal the heat units from 1 square foot of radiator per 1 degree difference of temperature for conditions corresponding to the guarantee ; let c' denote the same values for other conditions ; let x equal resulting temperature of room, t'' outside air for the actual conditions, R equal square feet of radiation.

For guaranteed conditions,

$$(t' - t)\, B = c\, (T - t')\, R$$

* In America.

For actual conditions,

$$(x - t'') \text{B} = c' (\text{T} - x) \text{R}$$

Divided (1) by (2),

$$\frac{t' - t}{x - t''} = \frac{c\,(\text{T} - t')}{c'\,(\text{T} - x)}$$

When $t' = 70$, $\text{T} = 220$, $t = 0$,

and $c = 1 \cdot 8$, we have

$$c' \left(\frac{\text{T} - x}{x - t''}\right) = 3 \cdot 86."$$

Professor Carpenter, in a note under this rule, states that the heat transmission grows less as the inside temperature rises, and that, therefore, the equations can only be solved in an approximate manner. In working out an example case, the author of this formula states that an apparatus which will give an increase of 70°, from 0° to 70°, will register $104\frac{3}{4}$° when the outer air is 60°. This, although having a genuine respect for Professor Carpenter, I feel compelled to doubt, especially as the radiation allowed to afford this temperature is seldom, if ever, more than 30 square feet of hot water radiation or 20 square feet of steam radiation per 1000 cubic feet of space.

Having had occasion to decide a test in this way, one that required to be settled beyond dispute (and such occasions, more or less important, must arise to all many times), it was thought that a series of tests would or should give figures that could not be doubted, and as the tests proceeded there was a feeling of conviction experienced that something in the nature of a problem was being solved. The following are the selected temperatures taken, only representing a rather small proportion of the whole, but the recording cards have, on so many days, marginal notes which throw a doubt upon the results being obtained under what may be termed test conditions. Negligence, or over-attention at the furnace, alone spoiled many days' tests, and it will be seen in these selected that the temperature of the water was difficult to regulate with exactness. This was due to the boiler being fully powerful, requiring checking more than urging.

SELECTIONS FROM TEMPERATURES TAKEN.
Arranged in approximate order of out-door coldness.

Hour.	Outdoor Thermometers.		Indoor Thermometers.		Temperature of Water.	Weather.
	S.W. Aspect.	N. Aspect.	Room No. 1.	Room No. 2.		
	°F.	°F.	°F.	°F.	°F.	
10 a.m.	26	27½	59	54½	192	Bright, S.W. breeze.
11 "	28	29	59½	55	204	" "
12 "	30	32	60	56	206	" "
10 "	27½	29½	59½	53½	180	Bright, S.E. breeze.
11 "	30	31	60	54	184	" "
12 "	30½	31½	61	55	200	" "
10 "	28	30	61	54	190	Dull, E. breeze.
11 "	30	32	62	55	190	" "
12 "	32	34	62½	56½	200	" "
10 "	29	30½	60	56	200	Bright, E. breeze.
11 "	31	32½	60	56½	185	" "
12 "	30	31½	60½	57	180	" "
12 only	29	30	59½	56	182	Dull, N.E. breeze.
10 a.m.	30½	30	62½	—	200	Bright, still.
12 "	32½	33½	62	—	180	" "
10 "	35	36	63	57	200	Raining, E. breeze.
11 "	35	35	64	58	204	" "
12 "	36½	38	65	58½	210	" "
10 "	35½	36½	66	58½	210	Bright, W. breeze.
11 "	38	39	66	58	182	" "
12 "	41	42	65½	58½	175	" "
10 "	36½	36	64	58	190	Bright, S.W. breeze.
11 "	41½	40	65	58½	185	" "
12 "	43½	43	67	61	210	" "
10 "	38	40	64	56	196	Bright, W. wind.
11 "	40	41	65	56	189	" "
12 "	41	42	66	58	196	" "

SELECTIONS FROM TEMPERATURES TAKEN.—*continued.*

Hour.	Outdoor Thermometers.		Indoor Thermometers.		Temperature of Water.	Weather.
	S.W. Aspect.	N. Aspect.	Room No. 1.	Room No 2.		
	° F.	° F.	° F.	° F.	° F.	
10 a.m.	38	40	66	58	196	Mist, still.
11 „	39	39½	66	59	291	„ „
12 „	39	40	67	61	202	„ „
10 „	38½	39	65	59	192	Bright, S. breeze.
11 „	39½	39½	65	59	195	„ „
12 „	39	39½	65½	59½	204	„ „
10 „	39½	38½	60	58	192	Bright, N.E. wind.
11 „	40½	41½	61½	58	182	„ „
12 „	40½	41½	63	59½	182	„ „
10 „	41½	42	68	60	200	Bright, S.W. breeze.
11 „	43	43½	68½	60½	208	„ „
12 „	48	47½	69½	62	204	„ „
10 „	42	43	62½	57½	210	Wet, S.W. breeze.
11 „	43	44	63½	58	185	„ „
12 „	44	44½	64	58	176	„ „
10 „	41½	42	59½	56	175	Dull, N.W. wind.
11 „	41½	42½	64½	59½	193	„ „
12 „	41	42	65	60	192	„ „
11 „	44	42	—	61	198	Bright, W. wind.
12 „	44	42	66	60	190	„ „
10 „	44	44	67	61	184	Bright, W. breeze.
11 „	46	45	68	62	182	„ „
12 „	46	46	68	62½	180	„ „
10 „	45	45	66	59	183	Wet, W. breeze.
11 „	45	45½	67½	60	178	„ „
12 „	45½	46	68	60	178	„ „
11 „	44	46	67	62½	175	Raining, S. breeze.
12 „	44	46	68	62½	175	„ „

SELECTIONS FROM TEMPERATURES TAKEN.—*continued.*

Hour.	Outdoor Thermometers.		Indoor Thermometers.		Temperature of Water.	Weather.
	S.W. Aspect.	N. Aspect.	Room No. 1.	Room No. 2.		
	° F.	° F.	° F.	° F.	° F.	
10 a.m.	45½	46	66	63	195	Wet, still.
11 „	50	50	67	62½	175	„ „
12 „	52	52½	68	62½	180	„ „
10 „	47	47½	—	60½	188	Bright, S.W. wind.
11 „	47	47½	67	61	182	Dull, W. wind.
12 „	45½	46½	67	60	175	Wet, W. wind.
10 „	47	47	66	61	175	Bright, W. wind.
11 „	48½	48½	67½	61½	185	„ „
12 „	49½	49½	67	61	170	„ „
10 „	47	46	68	61	180	Dull, W. breeze.
11 „	48	47	68	60	190	„ „
12 „	48	47	69½	62	190	„ „
11 „	48	48	67½	61	200	Dull, W. wind.
12 „	48½	48½	68½	61	184	„ „
10 „	48	48	67	62½	190	Bright, E. breeze.
11 „	46	45	67	63	193	„ „
12 „	49	49	68	63½	180	„ „
12 only	51½	51½	69	62	180	Dull, S.W. gale.
10 a.m.	52	52	68½	63	175	Dull, S.W. wind.
11 none						
12 a.m.	53	53	70	64	180	„ „
11 „	52	51½	69	63	190	Dull, S.W. gale.
12 „	52	52	70½	63½	200	„ „
11 „	54	53	68½	63	185	Dull, W. wind.
12 „	55	53½	69	63	176	„ „
10 „	56	56	71	64	186	Bright, W. breeze.
11 „	57	56	70	65	180	„ „
12 „	57	56	71	64	184	„ „

From the foregoing temperatures the following table has been compiled. It is almost unnecessary to point out what a difference the temperature of the water makes to the internal temperature, and the tests illustrate this; and in arriving at the figures for the table it has been endeavoured to make correct allowance for the temperature prior to the figures being taken. It might have been mentioned earlier, that, although the figures are given for three different hours in a day, this was only done for the sake of the information it might afford, the actual test time being 12 o'clock (noon).

Table of equivalent temperatures to enable heating works to be tested when the temperature of the outer air is higher than that given in the contract or guarantee.

When the required rise in temperature is from 32° to 60° Fahr.

If outer air is	The internal temperature should be
32 degrees	60 degrees
34 ,,	61¾ ,,
36 ,,	63¼ ,,
38 ,,	64½ ,,
40 ,,	65½ ,,
42 ,,	66½ ,,
44 ,,	67¼ ,,
46 ,,	68 ,,
48 ,,	68¾ ,,
50 ,,	69¼ ,,
52 ,,	69¾ ,,
54 ,,	70¼ ,,
56 ,,	70½ ,,

It would seem desirable to suggest some rules or provisions when making tests.

In the first place, not less than two outside thermometers should be used, one on the sheltered and one on the exposed side of the building. In no case should the sun shine directly upon either of them, and the external temperature should be the mean of the two. As the external air is constantly changing in temperature (usually rising during the

SELECTIONS FROM TEMPERATURES TAKEN.—*continued.*

Hour.	Outdoor Thermometers.		Indoor Thermometers.		Temperature of Water.	Weather.
	S.W. Aspect.	N. Aspect.	Room No. 1.	Room No. 2.		
	° F.	° F.	° F.	° F.	° F.	
10 a.m.	45½	46	66	63	195	Wet, still.
11 "	50	50	67	62½	175	" "
12 "	52	52½	68	62½	180	" "
10 "	47	47½	—	60½	188	Bright, S.W. wind.
11 "	47	47½	67	61	182	Dull, W. wind.
12 "	45½	46½	67	60	175	Wet, W. wind.
10 "	47	47	66	61	175	Bright, W. wind.
11 "	48½	48½	67½	61½	185	" "
12 "	49½	49½	67	61	170	" "
10 "	47	46	68	61	180	Dull, W. breeze.
11 "	48	47	68	60	190	" "
12 "	48	47	69½	62	190	" "
11 "	48	48	67½	61	200	Dull, W. wind.
12 "	48½	48½	68½	61	184	" "
10 "	48	48	67	62½	190	Bright, E. breeze.
11 "	46	45	67	63	193	" "
12 "	49	49	68	63½	180	" "
12 only	51½	51½	69	62	180	Dull, S.W. gale.
10 a.m.	52	52	68½	63	175	Dull, S.W. wind.
11 none						
12 a.m.	53	53	70	64	180	" "
11 "	52	51½	69	63	190	Dull, S.W. gale.
12 "	52	52	70½	63½	200	" "
11 "	54	53	68½	63	185	Dull, W. wind.
12 "	55	53½	69	63	176	" "
10 "	56	56	71	64	186	Bright, W. breeze.
11 "	57	56	70	65	180	" "
12 "	57	56	71	64	184	" "

From the foregoing temperatures the following table has been compiled. It is almost unnecessary to point out what a difference the temperature of the water makes to the internal temperature, and the tests illustrate this; and in arriving at the figures for the table it has been endeavoured to make correct allowance for the temperature prior to the figures being taken. It might have been mentioned earlier, that, although the figures are given for three different hours in a day, this was only done for the sake of the information it might afford, the actual test time being 12 o'clock (noon).

Table of equivalent temperatures to enable heating works to be tested when the temperature of the outer air is higher than that given in the contract or guarantee.

When the required rise in temperature is from 32° to 60° Fahr.

If outer air is	The internal temperature should be
32 degrees	60 degrees
34 "	61¾ "
36 "	63¼ "
38 "	64½ "
40 "	65½ "
42 "	66½ "
44 "	67¼ "
46 "	68 "
48 "	68¾ "
50 "	69¼ "
52 "	69¾ "
54 "	70¼ "
56 "	70½ "

It would seem desirable to suggest some rules or provisions when making tests.

In the first place, not less than two outside thermometers should be used, one on the sheltered and one on the exposed side of the building. In no case should the sun shine directly upon either of them, and the external temperature should be the mean of the two. As the external air is constantly changing in temperature (usually rising during the

SELECTIONS FROM TEMPERATURES TAKEN.—*continued.*

Hour.	Outdoor Thermometers.		Indoor Thermometers.		Temperature of Water.	Weather.
	S.W. Aspect.	N. Aspect.	Room No. 1.	Room No. 2.		
	° F.	° F.	° F.	° F.	° F.	
10 a.m.	45½	46	66	63	195	Wet, still.
11 „	50	50	67	62½	175	„ „
12 „	52	52½	68	62½	180	„ „
10 „	47	47½	—	60½	188	Bright, S.W. wind.
11 „	47	47½	67	61	182	Dull, W. wind.
12 „	45½	46½	67	60	175	Wet, W. wind.
10 „	47	47	66	61	175	Bright, W. wind.
11 „	48½	48½	67½	61½	185	„ „
12 „	49½	49½	67	61	170	„ „
10 „	47	46	68	61	180	Dull, W. breeze.
11 „	48	47	68	60	190	„ „
12 „	48	47	69½	62	190	„ „
11 „	48	48	67½	61	200	Dull, W. wind.
12 „	48½	48½	68½	61	184	„ „
10 „	48	48	67	62½	190	Bright, E. breeze.
11 „	46	45	67	63	193	„ „
12 „	49	49	68	63½	180	„ „
12 only	51½	51½	69	62	180	Dull, S.W. gale.
10 a.m.	52	52	68½	63	175	Dull, S.W. wind.
11 none						
12 a.m.	53	53	70	64	180	„ „
11 „	52	51½	69	63	190	Dull, S.W. gale.
12 „	52	52	70½	63½	200	„ „
11 „	54	53	68½	63	185	Dull, W. wind.
12 „	55	53½	69	63	176	„ „
10 „	56	56	71	64	186	Bright, W. breeze.
11 „	57	56	70	65	180	„ „
12 „	57	56	71	64	184	„ „

From the foregoing temperatures the following table has been compiled. It is almost unnecessary to point out what a difference the temperature of the water makes to the internal temperature, and the tests illustrate this; and in arriving at the figures for the table it has been endeavoured to make correct allowance for the temperature prior to the figures being taken. It might have been mentioned earlier, that, although the figures are given for three different hours in a day, this was only done for the sake of the information it might afford, the actual test time being 12 o'clock (noon).

Table of equivalent temperatures to enable heating works to be tested when the temperature of the outer air is higher than that given in the contract or guarantee.

When the required rise in temperature is from 32° to 60° Fahr.

If outer air is	The internal temperature should be
32 degrees	60 degrees
34 ,,	61¾ ,,
36 ,,	63¼ ,,
38 ,,	64½ ,,
40 ,,	65½ ,,
42 ,,	66½ ,,
44 ,,	67¼ ,,
46 ,,	68 ,,
48 ,,	68¾ ,,
50 ,,	69¼ ,,
52 ,,	69¾ ,,
54 ,,	70¼ ,,
56 ,,	70½ ,,

It would seem desirable to suggest some rules or provisions when making tests.

In the first place, not less than two outside thermometers should be used, one on the sheltered and one on the exposed side of the building. In no case should the sun shine directly upon either of them, and the external temperature should be the mean of the two. As the external air is constantly changing in temperature (usually rising during the

SELECTIONS FROM TEMPERATURES TAKEN.—*continued.*

Hour.	Outdoor Thermometers.		Indoor Thermometers.		Temperature of Water.	Weather.
	S.W. Aspect.	N. Aspect.	Room No. 1.	Room No. 2.		
	° F.	° F.	° F.	° F.	° F.	
10 a.m.	45½	46	66	63	195	Wet, still.
11 „	50	50	67	62½	175	„ „
12 „	52	52½	68	62½	180	„ „
10 „	47	47½	—	60½	188	Bright, S.W. wind.
11 „	47	47½	67	61	182	Dull, W. wind.
12 „	45½	46½	67	60	175	Wet, W. wind.
10 „	47	47	66	61	175	Bright, W. wind.
11 „	48½	48½	67½	61½	185	„ „
12 „	49½	49½	67	61	170	„ „
10 „	47	46	68	61	180	Dull, W. breeze.
11 „	48	47	68	60	190	„ „
12 „	48	47	69½	62	190	„ „
11 „	48	48	67½	61	200	Dull, W. wind.
12 „	48½	48½	68½	61	184	„ „
10 „	48	48	67	62½	190	Bright, E. breeze.
11 „	46	45	67	63	193	„ „
12 „	49	49	68	63½	180	„ „
12 only	51½	51½	69	62	180	Dull, S.W. gale.
10 a.m.	52	52	68½	63	175	Dull, S.W. wind.
11 none						
12 a.m.	53	53	70	64	180	„ „
11 „	52	51½	69	63	190	Dull, S.W. gale.
12 „	52	52	70½	63½	200	„ „
11 „	54	53	68½	63	185	Dull, W. wind.
12 „	55	53½	69	63	176	„ „
10 „	56	56	71	64	186	Bright, W. breeze.
11 „	57	56	70	65	180	„ „
12 „	57	56	71	64	184	„ „

From the foregoing temperatures the following table has been compiled. It is almost unnecessary to point out what a difference the temperature of the water makes to the internal temperature, and the tests illustrate this; and in arriving at the figures for the table it has been endeavoured to make correct allowance for the temperature prior to the figures being taken. It might have been mentioned earlier, that, although the figures are given for three different hours in a day, this was only done for the sake of the information it might afford, the actual test time being 12 o'clock (noon).

Table of equivalent temperatures to enable heating works to be tested when the temperature of the outer air is higher than that given in the contract or guarantee.

When the required rise in temperature is from 32° to 60° Fahr.

If outer air is	The internal temperature should be
32 degrees	60 degrees
34 ,,	61¾ ,,
36 ,,	63¼ ,,
38 ,,	64½ ,,
40 ,,	65½ ,,
42 ,,	66½ ,,
44 ,,	67¼ ,,
46 ,,	68 ,,
48 ,,	68¾ ,,
50 ,,	69¼ ,,
52 ,,	69¾ ,,
54 ,,	70¼ ,,
56 ,,	70½ ,,

It would seem desirable to suggest some rules or provisions when making tests.

In the first place, not less than two outside thermometers should be used, one on the sheltered and one on the exposed side of the building. In no case should the sun shine directly upon either of them, and the external temperature should be the mean of the two. As the external air is constantly changing in temperature (usually rising during the

morning hours), it cannot be correct to take the external figures either at the beginning or end of the test, and it would appear best to take them when the test is half through.

As to the time to test, this should invariably be during the morning hours, as early as possible, for it may be supposed that an apparatus is installed with a view to giving the agreed warmth as soon as reasonably possible after the rooms or place may be occupied. In the case of factories and works, also in private residences, the apparatus would probably have the fire alight all night, for without this provision it would be well on in the morning before the boiler would be giving its full results, and this with many businesses and purposes would entail annoyance if not loss.* If a place is occupied an afternoon test is out of the question, as the heat from workers' machines, or from other sources, and many happenings, all go to give unreliable results, though usually in favour of the heating engineer.

There should be two or more indoor thermometers hung free in the air, and at about 5 feet from the ground; and, needless to say, the whole of those used should be exactly alike in their recording qualities.

It is always best to test when a place is fitted or furnished, occupied and in normal use, and what has already been said is based largely on this. Unfortunately such a test is not always possible, and there arises the question whether allowances, and what allowances, may be necessary when testing in new, unoccupied buildings of any kind. Few can have had experience sufficient for them to say that a certain allowance is strictly correct, but as I have lived in a house, not for a few days, but some months, with parts of it in both conditions, a degree of confidence is felt in saying 3° should be allowed when freezing; or equivalent when the outer air is warmer. It will be understood that this means that an apparatus intended to give an internal temperature of 60° when 32° outside should be considered satisfactory, if it gives a 57° warmth in an unfurnished, unoccupied building when 32° out-

* In printing and lithographic works the ink will not flow properly until 58° to 60° is registered.

side; or an internal temperature of say 62½° when 38° outside. This is a detail that will well bear discussion, being a source of many disputes of a serious nature. In some instances the internal temperature is specified as being that "when the building is empty and unoccupied," but a qualification of this kind is rare, and the temperature mentioned is almost always that which is required (as being agreeable or suitable) when the place is regularly occupied and used.

As to the time occupied in making a test, if the fire is alight the whole previous night, then two hours in the morning should suffice, whether the apparatus be small or large. This is based on the supposition, a reasonable one it is believed, that a place, whatever its kind, is required to be of a comfortable temperature within two hours after the attendant revives the fire in the morning. This needs consideration in erecting an apparatus, for in so many instances the night fire is essential to success, and, when no night watchman is employed, it requires a good boiler to keep a little warmth in the place for 12 to 14 hours without attention. It is not, however, so difficult with hot water as with steam, though this advantage possessed by water is somewhat counterbalanced by the greater rapidity with which full heat is obtained in steam pipes, when the fire is urged. If by any chance a test for temperature is required without the fire being alight through the night, then the period of time to be allowed for the test is an uncertain quantity, for it must depend on the size of the installation and the conditions. It should, therefore, be stipulated in every possible case that the fire be lighted the previous day, be attended to or banked up during the night, and then the test be made in the morning hours. This is only a fair provision for the heating engineer, while being equally fair to the client or his representative.

The upper limit of external temperature, 56°, is quite high enough, for above this temperature, such an exceedingly small rise is obtained inside for one or two degrees outside. Even a quarter of a degree is not easily read off ordinary thermometers, nor are ordinary thermometers always correct to this extent.

CHAPTER XI.

DRYING ROOMS.

THE successful working of a drying room depends wholly on furnishing it with air that is deficient in moisture, and is, so to speak, thirsty. This air will, then, readily absorb the moisture that is in the goods to be dried. It cannot be too clearly understood that heat has no direct drying effect in itself. It is a common impression that to subject a wet or damp substance to heat causes it to become dry, and the greater the heat is the quicker the drying will be. Heat certainly aids in the drying process, and is used with great advantage in all drying rooms, but it has no direct drying effect, as can be shown. A very convincing instance came to the writer's experience in a brush manufacturing works. Here was built a drying room for the washed and bleached or stained fibre. It was heated by steam pipes, and the work in this respect could not be better, but the materials put in the rooms did not dry even in so long a period as three days. They became hot, but they then only differed to their original state by being hot and damp, instead of cold and damp. They were absolutely moist after three days' heating, when the writer viewed the job.

The failure was due to the absence of ventilation. It is air that can and does deprive goods of moisture, but the useful aid that heat affords lies in the fact that heated air is more effective in robbing goods of moisture than cooler air is. Air has a capacity for moisture, it might be said an affinity, for if air is deficient in moisture (dry as it would be termed), it will pick up water wherever it can, and there is no hesitation or delay in its doing this. If dry air is introduced to wet goods, it needs no mechanical or other aid to make it rob the wet

goods of moisture. All that is necessary is to bring the air and the goods together, so that the air may readily do its part.

The reason for warming the air is simply explained. Air at, say, 50° F. temperature can absorb and carry 4¼ grains of water per cubic foot. At 80° it can take 10¾ grains, while at 100° the quantity is increased to 19⅛ grains, and so on. (See table in Appendix.) If, therefore, we have air at 50°, and heat it to 100° as it is entering the drying room, it will be capable of absorbing moisture to a considerable extent, but what has to be particularly explained is that the heated air is not only capable of absorbing moisture, but it is thirsty, if it may be so expressed, and will greedily take up water from whatever moist or damp substance it may come in contact with. It is not a question of making the heated air pick up the moisture; the difficulty would be to prevent it. Let it be clearly understood that nothing is done to the air except to heat it, that is, to make it pass over some kind of hot surface that will raise its temperature. The air at 50° might and doubtless would be reasonably moist, probably carrying fully four-fifths its total moisture per foot, and would be considered humid enough for respiration and general comfort *; but on raising the temperature, the dryness becomes very pronounced, although the air will have lost none of its original moisture. In other words, the full moisture that air has at 50° is quite insufficient for the same air at a higher temperature, and the effect of the heat is to make the air take moisture from the first damp substance it meets. Briefly, therefore, the drying process is the absorption of moisture by the air in contact with the damp goods, and this process of absorption is greatly increased and hastened by heating the air, as this gives it a greater capacity for moisture.

The next detail of the drying process to be pointed out is that there is an early limit to the amount of moisture a certain

* It may be explained that the atmosphere is seldom fully saturated, that is, carrying its utmost limit of water. Its natural degree of humidity varies with the weather, for while the mean humidity from September to March has been found to be from 81 to 89 per cent., in April to August it has only been from 74 to 79 per cent. (complete saturation = 100).

volume of air can absorb from damp goods, and although air at 100° will take about four and a half times as much water as air at 50°, it will take no more. It is, therefore, of no use filling a drying room with heated air and expecting this one charge of air to dry the wet goods. One charge of air, though doing good work, really does exceedingly little, and the efficiency of a drying room lies very greatly in its ventilation. There must be a positive and continuous change of air, new dry and thirsty air coming to the damp goods, and a corresponding exit of the air that is loaded with moisture, and which has lost its drying properties by having no further capacity for moisture. After the air in a drying room has taken up its full charge of moisture, it is useless keeping it there, and the sooner it escapes the better. What is wanted is air that is in need of moisture, and as soon as its need is satisfied it must be got rid of.

In arranging the heating and ventilating of a drying-room, therefore, the erroneous idea that putting the wet goods into a warm atmosphere will dry them must be quite abandoned. First decide the area of heating surface required, then see how it can be disposed in relation to the ventilation. The incoming air must be made to pass over the hot pipes or surfaces to heat this air. On no account must any idea be entertained of disposing the heating surface so as to afford warmth to the wet goods, for this is quite a wrong way to go to work. All that must be done is to heat the incoming air and thus increase its capacity for moisture and make it seek for more. The inlet of new heated air, and the outlet of saturated and useless air, must also be disposed so that the new air passes over or through the wet goods to get at the outlet. If the inlet and outlet were so arranged that the air movement did not have good contact with the wet goods, then the drying could not be successful.

The least size of fresh air inlet and the moist air outlet should be one square foot area for every 500 cubic feet of space in the drying room (when empty). This would be for a room say 8 feet each way. With most drying rooms it is important that the air be clean (in laundry work for

example), and if it is a manufacturing or thickly populated district, the air should be filtered through muslin or cheese-cloth, either of which must be cleaned or changed frequently. Even for country districts a wire gauze strainer must be used to arrest particles of dirt, insects, etc.

As to inducing the necessary air movement through a drying room, this can be effected by mechanical or by natural means. By mechanical is meant the use of a fan or blower, but whenever possible the natural means is preferred as costing the least and needing the least attention. Natural ventilation is that brought about by the up-current, the draught, that occurs in brick-built chimneys. If the drying room has such a chimney of at least twice the height of the room, the extraction of saturated air should be all that is needed, as, failing a sufficient draught, it can easily be provided with a gas ring at its base, or some similar means of inducing an active up-current. The chimney thus becomes the extractor, and supposing its top extremity to be above the building, so as not to suffer with down-blow, the change of air in the room should be all that is desired.

In Fig. 55 is suggested a drying room in which it is supposed that the wet material can be spread out on lattice shelves or trays, through which the air can circulate. It will be understood, however, that the requirements in this work differ greatly and need different treatment, but in every case the principle laid down must be observed to ensure efficiency. It is that air is the drying medium, this being made more effective by warmth; and the warmed air must pass close over or through the goods to be dried and then, when loaded with moisture, be carried away as quickly as possible.

It is never desirable to have the heating surface on the floor near the centre, or in a central trench beneath the floor, even though a fresh air duct can be brought to it. In such situations the pipes get loaded with dust and dirt and every effort should be made to keep the pipes away from such a situation.

Although this book deals with hot-water work it may be stated that the heat afforded to the air of drying rooms is

usually effected by steam pipes or by a stove. Hot water is scarcely hot enough. Steam is at least 212° and usually much hotter than this, as 40 lb. to 60 lb. steam is often available in factories and such places. Stove heat is even better if a high temperature air is admissible. Stoves of various kinds are to be readily obtained suited to this work, those adapted for Turkish bath work being quite suitable. They are ingeniously designed stoves with cast iron shells either

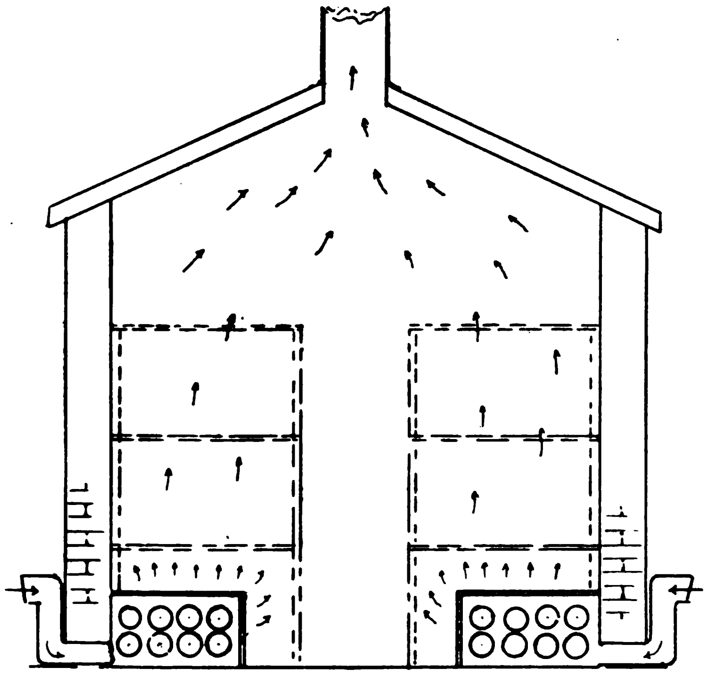


FIG. 55.

gilled or broken up by convolutions, but in either case presenting surface that will make air as dry as could be desired, yet not dangerously hot or deficient in hygienic qualities (except humidity). When using a stove it is fixed somewhere outside the drying room, and the dry air is conveyed in metal or stoneware ducts (drain pipes) and discharged in the room where it will effect its purpose best. The same plan could be

adopted with steam or hot-water pipes if so desired. There is no need for them to be in the drying room, if it is more convenient to put them elsewhere. They can be made into stacks in a heating chamber (see gilled pipes and radiators on page 5), and from this source the heated air could be taken by ducts to the drying room. In all these cases the extract ventilation is relied on to make the warmed air flow to and enter the room, for it will not enter otherwise. Extraction there must be, or the new air, warm or cold, will not enter the room.

The amount of heating surface required for this work is given in the table of quantities on page 106. With steam at 10 lb. pressure as the heating medium, the surface given in the table may be reduced one-third, while at higher pressures the area may be reduced one-half.

CHAPTER XII.

AIR IN PIPES—LOSS OF HEAT—CONDITIONS WHICH INTERFERE WITH THE CIRCULATION —CAUSES OF FAILURE—CHIMNEYS—DECORATING RADIATORS—COVERING PIPES, ETC.

It cannot be too plainly stated that air can give as much, if not more, trouble to the heating engineer than any fluid or solid substance he has to deal with, yet the study of this detail is much neglected, probably more than any other. Numberless are the failures in apparatus which appear to be erected on perfect lines, the failure being wholly due to air, not even assisted by faulty construction. Take the following instance, for example. A properly designed apparatus, of a good size and extent, was filled, and, after inspection, tested with the fire alight. One branch or section of the apparatus failed to heat, and the writer's opinion was asked. There might be several causes of this failure, as will be learned in this chapter, but by good fortune the actual cause was diagnosed at once. It appears that for want of sufficient assistance the fitter had charged the apparatus with water with all the air cocks closed, and he afterwards went round and opened them to discharge the air and allow the water to follow up and enter the radiators and pipes. This is a practice often indulged in, for, with a large apparatus, and sometimes a small one, it is difficult to charge with all air-cocks open, as this means a sudden issue of water at all the cocks on the same level, when the air is discharged, and a difficulty in running round to close all the cocks before the issue of water has done any damage. It will be understood that if a dozen radiators were on a floor, there would be a

dozen air cocks discharging air, all of which would have water following the air almost simultaneously, and perhaps only two men to get these cocks closed on the arrival of water from them. The consequence is that the cocks are kept closed, and the man or men go round and open them to discharge the air, one at the time, afterwards. This is what had been done in the case cited, and the result was the very common one attending the practice, air locked in one of the pipes. The question was asked if the apparatus had been charged with all the air cocks open, and the answer was no, they had been kept closed and opened afterwards. It was then suggested that before any expense was incurred that the apparatus should be emptied,* and refilled slowly with all air cocks open, to ensure all air being discharged as fast as the water could rise behind it, and the result was an entire success.

In filling an apparatus, means must be adopted to ensure all air being expelled as the water enters and rises up in the pipes and parts. This is the reason why the cold supply is connected to the lowest point in the apparatus (see p. 47), but the expense of bringing the cold pipe to the lowest point can be defeated, temporarily, at least, by charging with the air cocks closed. What happens is that the water works along the pipes past the air that is enclosed, and then when the air cocks are opened advance water may reach the vent before the air behind it can get there, and trouble commences from that moment. It is probably thought that while the air cocks are closed the air remains in front of the water, that is, at the highest parts, but in practice this cannot be relied on, though it often happens. It is in horizontal pipes that the water will work along and cut off the air, and the rule should be, whatever the inconvenience or difficulty, to have all air vents open when charging an apparatus with water. If necessary, assistance should be borrowed from

* When emptying an apparatus all air cocks should be opened at the earliest moment, for water will not flow out of pipes if air cannot get in, and if water is left hung up in the branches, the subsequent refilling may be imperfect by air being locked between the incoming water and that which has been retained.

other trades in the building, or from outside, for the brief time the filling takes.

For the reason just stated an apparatus might with advantage have air pipes instead of air cocks, as the pipes are always open whether at first filling or subsequently. This, however, is seldom possible, except in horticultural works or an apparatus confined to one floor level. Even in the latter case, however, the air pipe, small as it may be, is not always allowed in residence work. If the pipe could be chased into the wall, it might do, but, failing this, the nickel-plated air cock has a far better appearance than an air pipe or pipe connection.

It may not be generally recognised that the chief reason

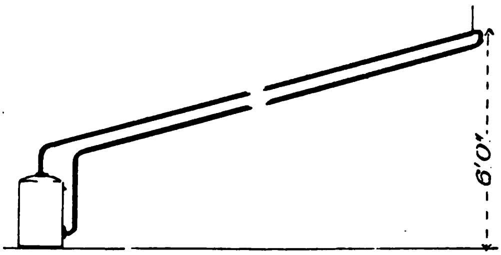


FIG. 56.

for giving a rise to hot-water circulating pipes * is to admit of air escaping freely. Many people think that the rise is to ensure the circulation occurring, or to favour it, but it is not so, for a circulation extending to the same height, either as Fig. 56 or Fig. 57, will work equally well if it could be ensured that the latter would keep free and clear of air.

At first filling, an apparatus of quite a bad design may fill properly and a circulation occur, but after working for a time (or if it has to be emptied and refilled), the good results fail. Water carries a good volume of air, and when heated will give it off in the boiler or pipes; consequently, when an apparatus is newly filled, or when it is periodically replenished, some free air will soon appear in the apparatus

* The least rise is 1 inch in 10 feet, but this should be exceeded whenever possible.

and must have a free exit, or passage to a point where it will give no trouble. If pipes are horizontal or have insufficient rise, the air will hang along in huge bubbles as Fig. 58, and as there are no large taps to be opened on this apparatus, there are no rushes of water or other disturbances to move the air. In the flow-pipe the direction of the circulation and the direction in which the air should travel to make its escape are usually alike, but even this fact makes but little difference to the air movement. The air appears to be stuck to the pipes, and a simple experiment with the glass model apparatus, recommended on page 21, will show that the circulatory movement, while as active as it can be through a pipe half choked with air, makes not the least impression in causing the air to move. The circulation will be seen occur-

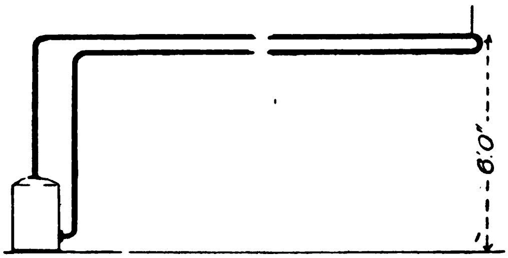


FIG. 57.

ring as shown by the dotted lines in Fig. 58, slipping past the imprisoned air as if it was solid material. It is to prevent air locating itself along the circulating pipes that a rise is given to the pipes, and although one inch in ten feet will suffice when no better rise can be got, it is not as successful as it might be, as experiment will show; one inch in five feet is better. It will be found that small pipes require more rise than large ones to keep them free of air; and let it always be remembered that in a heating apparatus the air has to escape of its own accord, which is quite different to the assistance it gets in a domestic hot-water supply apparatus on which ½-inch and ¾-inch taps are being opened many times a day. In such works the difficulty might be to keep

air in the pipes, if it was wanted there, for an open $\frac{3}{4}$-inch tap branched from a 1-inch main circulation will sweep air out quicker than it could be followed with the eye. In the heating apparatus any assistance of this kind is totally absent.

Troublesome results, due to air, quite commonly occur when dips are made in horizontal circulating mains or branches. The common impression is that the dip interferes with or prevents the circulation, that its existence is a power, or exerts a power, that counteracts the force of the circulation, and so brings it to a standstill, or nearly so. On the contrary it may be said that dips, as ordinarily made to pass doorways for instance, are nearly always permissible, it being quite the exception and not the rule for them to be otherwise; but unless certain precautions are taken, trouble and a stoppage of the circulation may result. Dips do certainly cause a power to be exerted contrary to the progress of a

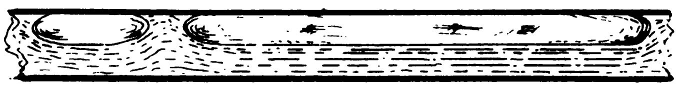


FIG. 58.

normal circulation, that is, favouring a retrograde circulation; but with dips of about 12 to 18 inches depth and 4 to 6 feet length their harmful power is so feeble as to be unnoticed even in an apparatus wholly confined to one floor.

To show the effects of air with a dipped circulation a very obvious example, an actual instance, may be given in Fig. 59. This was an apparatus erected to heat a small place of worship, a single-pipe 2-in main passing round the wall and carrying four 30-feet radiators. At the point shown a dip was made to pass a vestry doorway, and as the expansion pipe on the highest point existed where shown, it was, somewhat naturally, considered that an air-cock on the further side of the dip would suffice.

In ordinary working, this arrangement would do quite well and, as the results showed, the first filling and testing with the fire alight gave quite satisfactory results, but there was a leak

or two, which necessitated emptying the apparatus and subsequently refilling. On this being done it was found that the apparatus was as much a failure as it had previously been a success, and it required a deal of explanation to show that the two different results were due, the first to the apparatus being new and therefore quite empty when first charged and tested with good results, the second to the fact that the dip was already full of water when the apparatus was recharged.

The fault wholly lay in the dip not being vented on both sides, and it may be added that for perfect results the vents should be pipes and not cocks, unless care is taken to fill slowly with the cocks full open. These dips *must be vented*

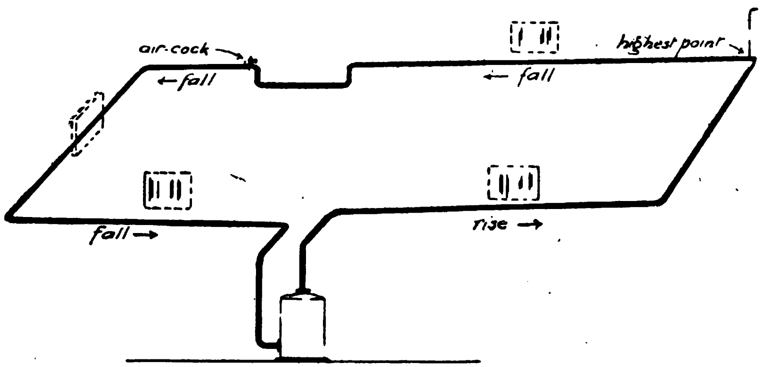


FIG. 59 (illustrating a fault).

on both sides, but the necessity of this only arises when the apparatus is being charged with the dip already full of water. It would be an equally good measure to arrange for the dip to be emptied previous to recharging, but this is not necessary, if each side of the dip is vented. Of course every dip requires an air-vent on one side for ordinary working, as one side must be the highest point of that part of the circulation, and cut off, by the dip, from the ordinary highest point. This had been put in the example just given, but the vent for discharging air when refilling had been omitted.

Another cause of air-lockage, which, although fairly well known now, has hitherto been overlooked or not understood,

is the use of an improper kind of stop-valve. The customary plan when connecting radiators now is to use the angle-valve, as shown in Fig. 37, p. 73, this valve being illustrated and described in the next chapter (Chapter XIV.). It is quite impossible to have air locked in this valve, and its construction admits of its having a nearly full way or passage through it. As near as appears to be possible, a 1-inch valve of this kind has a fairly clear 1-inch way through it, when is is fully open.* Where trouble has occurred is in the use of what may be termed the ordinary kind of screw-down stop valve, a section of which (one of a good make) is given in Fig. 59*a*. This is a valve that is fixed in a straight run of pipe (the opposite of an angle valve), and the up-and-down way through the valve must cause air to be locked in the pipe, whichever way the valve is turned. Air (in heating works) will not descend to pass an obstacle, consequently the ignorant use of this valve has often caused trouble. When no other valve is obtainable or possible, then a skilled engineer may use this one which has just been condemned, but he fixes it on its side—horizontally as it is called. The air cannot then be locked in so readily, but the valve is still faulty by having a very crooked and confined way through it. While we have the angle-valve, for angles, and the gate, or Peet's valve, for straight runs, the use of the other valve may cease with advantage.

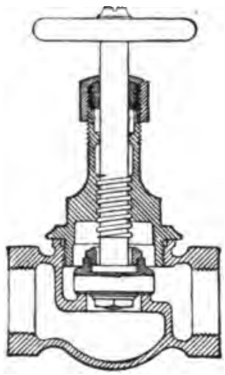


FIG. 59A.

The cold supply service can be made to give trouble by air collecting in it, and by air being locked on the supply side of a dip. In an instance that came to notice, the cold

* It has always seemed most unreasonable to give sizes to valves which they do not possess except at their screwed ends. According to the kind of valve that is being used or examined, it will be found that a 1-inch size may have a ½-inch to ¾-inch way through it, and from this it may be anything up to 1-inch clear. The writer's contention is that a 1-inch valve should have a 1-inch way through it, as straight and clear as possible, and other sizes accordingly.

supply to a boiler was as Fig. 60, and although the apparatus had worked well when first filled, it had given trouble since it had been emptied and refilled for some purpose. After a thorough examination no fault could be found, and the fact of the apparatus being partially empty could not be discovered, as all vents were air-pipes. It was subsequently found that water did not enter the apparatus as it should do, and there was the clearest proof that when an attempt was made to recharge the apparatus with the deep dip in the cold supply already full of water, the water carried air down into this pipe, and locked it there. Had this dip been down near the boiler it might possibly have happened that the head of water would carry the air right through, instead of its holding itself up in the high loop, but a perfect remedy resulted when the cold supply was re-arranged, as shown on page 48, and as it always should be.

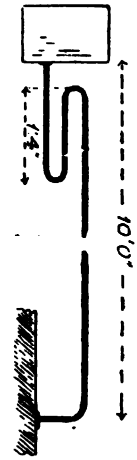


FIG. 60.

Air-pipes, too, can be a means of locking air in an apparatus, if they are not properly run. They must have a rise from the pipe or radiator that they are venting, all the way to their highest extremity. If there is a dip in any part of the pipe containing water, then air will collect in the high point on the boiler side of the dip, and there is nothing to make it work beyond there. If there is a dip in the empty part of the air-pipe, then this dip will soon have water collect in it, and so obstruct the free exit of air. Both cold-supply services and air-pipes must be run properly, the former with a gradual fall all the way towards the boiler, the latter with a gentle rise all their length from the radiator or pipe they are attached to.

In an earlier part of this book, when speaking of expansion pipes (p. 42), it was explained that this pipe need not be on the highest point of a circuit, if a radiator was there, as the latter would take the air that collected, and only need to have its air-cock opened now and again to discharge the air. A radiator of an ordinary kind has accommodation for a fair

volume of air at its top, without noticeably affecting the circulation of water within it and its general efficacy; therefore a radiator answers well to vent a high point, if the expansion pipe or an air-pipe cannot be put there. What has to be guarded against is attempting to vent a high point in a main or branch circulation with an air-cock. It is sure to be neglected, even if a pipe is brought down (with the cock on the end of it) to a convenient point for regular attention. It would require to be opened with some frequency, as even a small volume of air will impede the circulation to some extent. What must be aimed at in cases such as these is the free and instant escape of all air that collects at high points in circulating pipes.

When an apparatus fails to heat from insufficient boiler power the result often puzzles the inexperienced by the failure being confined to a part of the work, and not to the whole. It would be reasonable to expect that a boiler under power would show its weakness everywhere, the whole apparatus working sluggishly, and heating badly. Instead of this the more customary result is for a part of the apparatus to heat well, or fairly well, while another part, or parts, quite fail. This is, of course, supposing that the apparatus is not one single circuit, but consists of two or more sections. Sometimes the difference in results is so marked as to make it appear certain that the fault is a stoppage of some kind in the cool section, as the other part works so freely, and heats so well. It is difficult to diagnose the fault in such cases; but measurements and tables soon show what the fault may reasonably be attributed to. What is intended to be conveyed by this, is, that the failure of the water to heat in a branch or section of an apparatus is not always an indication of anything being wrong in that part, but may possibly be due to want of power in the boiler.

A similar faulty result to that just stated can be obtained by using pipes of insufficient size. This particularly refers to mains and branch mains. Supposing a main of insufficient size was put to supply, say, three branch circuits; the reason-

able assumption would be that if it could not carry water sufficient to keep them all hot, there would be a general shortage and want of heat in all alike. Instead of this, it is more likely than not that one or two of the circuits might heat well, or fairly well, and the other one or two be a complete failure.

Similar results are again obtained, when branch circuits or lines of pipes are badly arranged. In one instance that came to notice, a complete one-pipe circuit had been carried around a large building, and as there had to be some radiators in the centre, a central branch was carried across as Fig. 61. When

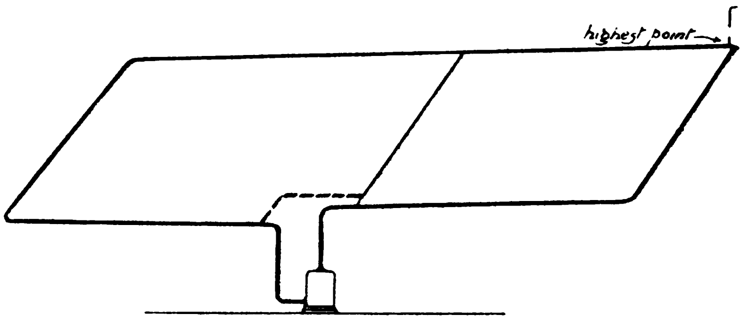


FIG. 61.

tested, the central pipe remained absolutely cold, while the outside circuit heated perfectly. It was not a case of air-lockage, nor want of boiler power or pipe area, yet, except for about two feet at each end of this pipe, the remainder of it might have been solid rod for all the circulation that occurred through it. A perfect remedy was found in making the central pipe a return instead of a flow, the connection being altered as shown in dotted line. It will be found in an earlier part of this book that while a return may be branched many times, and almost anyhow, a flow can only be treated in this way when the conditions are clearly correct and favourable.

When main pipes are too small, the bad results that must occur appear somewhat differently with the one-pipe and two-pipe systems. With the one-pipe, if it is a single circuit of

too small a pipe, it follows that the first radiators are much hotter than those that come after, and this occurs not only when firing up, but afterwards and at all times. The last radiator may only have water at about 70° F. in it, and only excessive firing will raise it to 100° or 110° F., and this is insufficient for cold weather. With the two-pipe system the result is usually short-circuit. This, as has been explained, is that a circulation occurs up to a certain branch or point, and beyond this the pipes are cold, and remain cold as if they were quite shut off from the main circulation.

Occasionally an apparatus, practically perfect in all details, may fail, due to the chimney being wanting in draught —that is a draught sufficient for the boiler. The subject of faulty chimneys is too long a one for these pages; but supposing that the chimney is of full height, and terminates well above surrounding buildings, so that it will not suffer with down-blow, then a rule that may be worked to is here given. A chimney, if too small, cannot cause air to pass through the boiler in sufficient volume to admit of combustion occurring freely, and a comparatively dull fire is the result. As a rule the fire is not conspicuously dull, and is, in this respect, misleading. It is found, however, that the water does not heat, and there is a feeling that the fuel is wanting in quality. The actual result is about the same as is obtained when a bright fire has the damper shut upon it; it remains quite a bright looking fire for a considerable time, but the heat it affords to the water falls off almost immediately the draught is checked.

All boilers, and iron or earthenware flue-pipe connections, must communicate with the chimney in an air-tight manner. Joints, at all points, must be soundly made—made in a manner to remain permanently air-tight, *for there must be no openings or crevices by which air can be drawn into the chimney without passing through the fire.* This is a golden rule to be observed in fixing boilers, or erecting flue pipe. *All air that enters the chimney must first pass through the fire.* There may be many boilers doing well, the fixing of which would go to prove this rule to be wrong; but because a chimney is a powerful

one, and can be robbed of some of its draught and yet supply the fire with all that it needs, is no proof that very many instances occur where this loss of draught means failure to the boiler. A boiler needs a certain volume of air, and the fixing should be done in a manner to ensure this being had. If the draught happens to be stronger than the boiler needs, then let the engineer feel satisfied that it is not the reverse, for while a strong draught is easily controlled by the damper, a weak draught means failure, more or less.

A rule that should be observed is, never put a boiler to a chimney that is less in diameter than the flue-nozzle on the boiler. With the small "Star" boilers, often used for heating a single room or some equally small job, it seems to be quite a common practice for those who fix them to make a reducing piece for their 6-inch nozzles, so that they may run the flue in 4-inch rain-water pipe. The writer once saw, incredible as it may seem, a 9-inch nozzle reduced and worked into a 4-inch cast flue-pipe. It was a total failure, and the fixer, a builder, said he considered it large enough. He acknowledged that if he was building a brick chimney for the boiler, he would have made it 9 inches by 9 inches, but being a pipe connection between a boiler and a brick chimney he considered 4 inches large enough.

With horticultural work the chimneys are usually low, and the effect of this is to make a greater area desirable. The sizes the writer has worked to for glass-house work are as follows:—

	Area of chimney. Square inches.
For a Trentham boiler 8 to 10 feet in length .	400
For a saddle or similar shaped boiler about 6 feet long	320
For a saddle or similar shaped boiler about 4 feet 6 inches long	250
For a saddle or similar shaped boiler about 3 feet long	200

These sizes are not according to any rule, but will be found to give satisfactory results where the low chimney is customary. Some authors consider that a chimney area of

12 square inches, per 100 feet of surface the boiler is capable of heating, is correct, and it doubtless is when the chimney is proportionately high. By this calculation a 6-foot saddle boiler would be given only 162 square inches, or, say, a 14-inch by 12-inch chimney instead of one 18 inches by 18 inches. As stated, both figures will be correct, if the height of the chimney varies considerably.

The more modern boilers, heating brick buildings in which the chimneys are high and have strong draughts, will work with chimneys of still smaller area. A list published by the American Radiator Company for their sectional boilers is as follows; and this list, under ordinary good conditions, may be relied on. Under no circumstances should a chimney be of less area than that of the nozzle on an independent boiler. The chimney itself should be a little larger, while the pipe connecting an independent boiler to a chimney should be of the same size as the nozzle (or larger if preferred).

Radiation in Square Feet.		Diameter of Chimney-flue in Inches.	
Steam.	Hot Water.	Round.	Square.
250 to 400	400 to 700	8	8 by 8
500 to 700	850 to 1200	10	8 by 12
800 to 1200	1350 to 2100	12	12 by 12
1400 to 2000	2400 to 3400	14	12 by 16
2200 to 3000	3700 to 5100	16	16 by 16
3500 to 5000	5900 to 8500	18	16 by 20

It may be noted that the sizes of square flues do not agree with those customarily built or found in English buildings. Our sizes usually run 9 inches by 9 inches, 9 inches by 13½ inches, 13½ inches by 13½ inches, 13½ inches by 18 inches, etc.; and it will be noted that the 9-inch flue-pipe so commonly used in this country is omitted entirely. If

this list is made use of, the nearest English sizes of the same area would be used.

To obtain the best results from any boiler, the flues must be kept clean. Whether it is an independent boiler with the flues contained in it, or a brick-set boiler, the metal surfaces of the flues must be clean, and the use of a wire flue brush—a brush in which stiff fine wire takes the place of bristles or fibre, is the correct thing to use. The metal surfaces want dry-scrubbing to clean them properly, and let it be remembered that the use of coke fuel does not make flue cleaning unnecessary, although it need not be done so often as when a bituminous fuel is used.

In the same way that a clean boiler surface is necessary for the proper absorption of heat, so is a clean radiating surface necessary for the proper distribution or loss of heat. Although the exposed radiator is now largely used, there are still works done in which the heating surface consists of pipes in trenches (with gratings over), also coils of pipes in coil-cases; and there are, of course, indirect radiators also encased. All these surfaces can readily get loaded with dust, but pipes in trenches, as in church work, are particularly liable to having dust and dirt material literally heaped upon them. As all dust and dirt consists of materials, which are poor conductors of heat (grit, which is chiefly silica, fibre, hair, wool, cotton, etc.), it follows that heating surfaces with no more than a moderate coating of this substance must have their heat diffusing qualities greatly retarded, and it is not unreasonable to suppose that the pipes in nearly all churches do little if any more than half the heating they are capable of. They cannot be kept clean by the ordinary church attendants, and there appears to be no arrangement as to their being cleaned by anyone else. It is a fault without any simple remedy, except to avoid putting pipes in trenches or cases whenever possible. The visible pipe or radiator always gets dusted and kept clean, but only these.

It has been explained that a very common cause of a branch circulation, or section of an apparatus, having the water remain stationary and cold in it, lies either in the boiler being

under power, or the main pipes too small, or a faulty arrangement of the connections, or filling in a manner that locks air in the pipes. In addition to these, there are occasional genuine instances of obstructions occurring in pipes, but such instances are not common. They may be often heard of, but on investigation one of the other causes just named is generally discovered. In horticultural work dirt will collect in pipes, and quite half fill them, or more, and this is due to the dirty pond or ditch-water used for replenishing the apparatus. This is a trouble that comes on gradually after a considerable period of time, and the only remedy is to take the pipes apart, and clean them.

With heating works in brick buildings, mud rarely appears in the pipes or boiler, nor is lime deposit ever a source of trouble, however hard the water may be. The reason for this is, that, although lime is precipitated when hard water is heated, the quantity of lime from one charge of water is exceedingly small, and as the water is not constantly changed, the deposition of lime may be said to be non-existent, for it is nearly so. There certainly is never sufficient to require removal, or to do any injury. In a domestic hot-water apparatus, which supplies water to baths and other taps, the change of water, that is, the new water that passes through the boiler, may amount to anything from fifty to two-hundred gallons per day ; while with a heating apparatus the replenishment, which means the introduction of new water into the apparatus, may be anything from one quart to a gallon or two per month. With the former kind of hot-water apparatus it is possible to get a half-inch deposit of lime in six months, while with the latter it would take a long life-time to get the same result. This is the reason that "furring" does not occur in a heating apparatus, although it may be filled from the same cistern as a bath supply apparatus, which "furs" badly.

As stated above, instances occasionally occur in which some solid material in a pipe interferes with the circulation in an apparatus, or a section of it, but such happenings are by no means common. Every fitter should make it a rule to

look through each length of pipe, as he uses it, to see that it is clear. It is such an easy matter for rubbish of some kind to get into a pipe, while it is travelling on the railway, or when lying about a job where other trades are at work. Again, it is the practice, when fitters leave a job for the night, to tuck a piece of cotton-waste or similar material in the open ends of the unfinished runs of pipe, and if pushed in a little too far it might be overlooked. Considering the tricks that boys and young mates get up to on jobs, it is a wonder that trouble of the kind now being discussed is not more common. Happily it is a comparatively uncommon trouble, but may be borne in mind when a difficulty arises. It is, however, more likely, in the majority of cases, that a retarded or faulty circulation is due to the other causes previously stated.

COVERING PIPES TO PREVENT LOSS OF HEAT.—It will be quite recognised, of course, that the purpose for which fuel is consumed in a boiler is to afford warmth in various rooms or places, where radiators or pipes are disposed for this purpose. It follows, therefore, that any heat diffused between the boiler and the rooms will probably be lost, and must, to a more or less extent, defeat the object for which the apparatus is erected. Loss of heat, too, is always a loss of fuel, as the two terms, heat and fuel, are practically synonymous in this work.

Although the foregoing may be recognised as being strictly correct and beyond dispute, yet the majority of heating works have exposed main and branch circulating pipes, uncovered and losing heat, and the wonder is that this is allowed to be so, when the loss is so real and so well known. It may often be true that the boiler is fully powerful, and the radiation fully sufficient, but this is no excuse for heat loss, and would rather go to show that a margin of boiler power and radiation was provided to meet it. It is wrong, and always wrong, to have heat dissipated from pipes which are expressly run to convey the heat somewhere else. The troublesome results are not confined to heat loss and waste of fuel, but are accompanied by delay in obtaining a full heat, while in some cases the full heat cannot be obtained at all.

The instances of reckless loss of heat that come to notice are numberless, making it appear as if the covering of pipes to prevent the loss was the exception and never the rule. Instances are met with in which the main circulation is run in the customary shallow space beneath the joists of a ground floor. It is a common practice, but if the pipes are uncovered, the heat loss is enormous. It is the coldest space in a building, and is always well ventilated to prevent "dry-rot" occurring. There must be times on winter days and nights when the pipes are robbed of heat as fast as they would be if run outside the house. In such situations and with all between-floor circulations the pipes should be covered thickly and well. The same applies with pipes in corridors and practically everywhere, for even if the pipes are run up the angles of warmed rooms (as in suites of offices, stores departments, etc.), they should still be covered. It should always be remembered that main pipes serve the special purpose of being conduits, to carry hot water, and they should conserve the heat of the water, not dissipate it. If radiators or radiating pipes are provided to afford warmth then the main is failing in its duty, so to speak, if it wastes heat on its way to the true heat distributing surfaces, as in every case there is loss of heat, fuel, time, and the desired results.

By referring to Chapter I., p. 3, it will be seen how greatly the conductive powers of materials differ, and while iron is a good conductor, which makes it serve the best of purposes in a boiler plate or a radiator casting, its good quality in this respect becomes a bad one, where the diffusion of heat entails a waste. As, therefore, the material of the pipe cannot be changed, recourse must be had to covering it with a substance that will resist the passage of heat. A very successful material is hair felt. This is cheap and easily applied, but it has a rough appearance, and is said to harbour insects. The writer has used great quantities of it, and never had the insect trouble that others say the felt is liable to, and he would not hesitate to use it again. The next material to hair felt in cheapness and efficacy is silicate cotton. This is a substance closely resembling cotton-wool, but it is really a

glass or silica-wool, a waste product from blast furnaces, and commonly called slag-wool. This has the advantage of being non-inflammable, but is difficult of application to pipes, unless they are surrounded with a wood or other casing, in which the wool can be packed. Certain factors of this material sell it sewn or secured on to a canvas backing, to admit of its being wrapped on pipes, and in this way it can be effectively applied, though it has as rough an appearance as hair felt when it is finished.

Asbestos does not rank as a particularly successful poor-conductor, although there is a common impression to the contrary. It is non-inflammable, and can be used if specified or desired, but may be said to be no better than half as good as hair felt or silicate cotton. There is no doubt that these two latter owe a large proportion of their efficacy to the numberless air spaces within their substance, for air is a good poor-conductor if it can be held in a great number of minute cells, and does not have a free circulation.

The felt and cotton named are the only two materials in general use, and failing these recourse is had to a composition. There are a number on the market, as reference to a directory or trade journal will show. It is doubtful if any of them are quite as efficient as the two loose materials stated, but they all rank as efficient in a general sense. The writer has used Fossil Meal, and found it successful; also a composition made by Leroy & Co. These are applied in successive half-inch coatings with a trowel, the last coating being finished off clean and smooth. It is best before applying the first coat to well rub some of the substance on to the metal surface, and let this dry. It will form a key for the next coat, and ensure better contact. As a rule, the boiler and pipes require to be moderately hot, when these materials are applied.

For common use a composition may be made up as follows:—A barrow-load of common clay, a barrow-load of fire-clay, a barrow-load of cowdung, a gallon of coal-tar, a quarter barrow-load of fine coal ashes or coke dust, and sufficient plasterer's hair to make the mixture bind. Mix all, adding water, if necessary, and make to the consistency of

stiff plaster. Make the boiler and pipes fully warm, then rub some of the material on (or thin some, and brush it on), and, when dry, apply ½-inch to ¾-inch coats, letting each coat dry before applying the succeeding one. Plaster can be added, if desired, while some put plaster in the last coat, so as to trowel it to a good finish. There should not be much, as these compositions require to be slightly elastic. From 1½ inch to 2 inches is the customary thickness of all composition coverings.

PAINTING RADIATORS.—The decoration of a radiator may not call for much description, but it is desirable to point out that the heating trade has been actually prejudiced by the ugly and depressing colours that radiators have been decorated (?) with. A colour that appears to have most favour is purple-brown, and it is difficult to imagine anything that gives a worse appearance and impression; even black would be better, if properly applied. There can be little doubt that the colours so commonly used, and which make radiators look so much like ironwork and factory goods, have retarded their use in residences and other good interiors. It matters not how beautiful the design of a radiator may be, if it is painted purple-brown, it will be instantly barred from entering any good residence. Ladies cannot see how nice a radiator can be made to look, when it is so coloured. White is the writer's favourite decoration, and it suits all radiators. With some it makes them look like porcelain, while the plainest are improved. Strange as it may sound, a white radiator is by no means a conspicuous object in a room. The white should be good and not assume a cream tint in the course of a short time. Either dead white or enamel look well, or the two can be worked together. If white is objected to, then make it an object to use light tints if anyway possible. They make a radiator less conspicuous than dark colours, and are pleasing to any eye that rests upon them.

Reference to p. 8 will show that all colours are available for this work, but a certain amount of doubt exists as to how bronze powders affect the radiating qualities of the surfaces

they may be applied to. In the majority of cases bronze powder decoration does not show the best taste, and might well be left out of use entirely.

On p. 56 is given particulars as to how the decoration of radiators entails some extra and special work, and this must always be borne in mind when estimating the cost of erecting an apparatus.

CHAPTER XIII.

BOILERS.

A NOVICE or beginner in heating work might suppose, on studying the different makers' catalogues, that amongst the great variety of makes and designs of boilers shown there must be at least a good number that serve special purposes, and included in the design of which must be some special detail or principle of construction to meet different specific requirements. It is scarcely so, however, and although there is generally some good reason for the variety it might all be summed up in saying that they represent successive improvements, and do little more than exhibit the efforts that are continually being made by manufacturers to do better than their rivals.

A representative variety of the boilers that are being made will be shown in this chapter, and the student who wishes to follow up this section of heating work will do well to note the description afforded with the examples, as the reason for, or utility of, the special features of the designs will be given with each. But before coming to this stage, a summary of essential points and their qualities may be given, and some information as to the value of heating surfaces.

The efficacy of a boiler lies chiefly in its heating surface, and it would be wholly so if it were not that the area of fire grating or bars must bear some sufficient proportion to the heating surface, if the latter is to be effectually heated. Again it might be said that efficacy must also depend upon the chimney; but for the purpose of the subject of this chapter it can be supposed that the chimney and accessory details of this kind are normally correct. The subject of boiler efficacy

is, therefore, reduced to the question of heating surface and grate area, the most important of which is heating surface.

Primarily there are but two kinds of heating surface, the Direct and the Indirect, but these may vary much in heating effectiveness. The direct surface is that which faces the fire—what the fire shines upon, and which *radiant* heat from the glowing mass of fuel chiefly affects. This surface also receives heat by contact with the incandescent fuel that rests against those parts which are near the fire-bars. There can be no doubt whatever that direct surface is the most valuable a boiler can have, and it will be found that the newest boilers on the market give evidence of effort being made to increase this surface by the most ingenious means, though, of course, the indirect or flue surface is not neglected.

The direct heating surface in a boiler may be said to be horizontal (over the fire) or vertical; but between these two there are angles of many different degrees, and which have a degree of efficiency relative to the two. It is very generally contended that a horizontal direct surface over a fire is the most valuable that can be had, and the heating of the familiar kettle is used to illustrate this. A kettle placed over a fire will have its contents boil much sooner than a kettle placed in front of a fire, supposing the area of heating surface and the state of the fire to be the same in each case, while a kettle placed beneath the fire would be much the least effective of all. This is a strictly correct argument when applied to a kettle or any water-heating device which can be subjected to an incandescent fire on all sides; but with the average boiler the decision arrived at will bear modifying. In the first place, the surface over the fire is only the most valuable when the top of the charge of fuel is in a glowing state. This is not always the condition of the fire, particularly in boilers constructed to take a charge of fuel to last several hours; or in boilers which are tended by unskilled persons, who heap fuel in with the idea of making the fire go as long as possible without being looked after; while, again, in mild weather the draught is reduced to a minimum which does not favour a fire having its top surface in a glowing condition.

All this tells against the heating surface over a fire and brings it nearer to being no better (if as good in some cases) than vertical surface, for included in the latter we get that surface which the glowing fuel, whether it be little or much, rests against.

The foregoing is not intended to deprecate the usefulness of direct surface, for under all conditions it remains the best that can be had. It is to show how varying its efficacy can be, and how impossible it is to set any precise working value on horizontal compared to vertical, or any degree between. The best that can be done is to consider direct surface as a whole and give it a general value accordingly, as is done a few pages further on. In all heating boilers effort is made by the manufacturers to increase the direct surface, for should any be sacrificed so as to gain more flue or indirect surface, then the latter must be at least three times as great before it has a working value equal to the direct surface lost, and would, of course, need to be four times the area to show an advantage or better results.

While on the subject of direct heating surface reference must be made to surface that comes beneath the fire. In the Trentham boiler for instance, (see page 171), this being a horizontal cylindrical boiler, about one-third of its inner surface comes beneath the fire-bars and forms the ash-pit. The writer believes that this is sometimes counted as direct surface, whereas its efficiency is less than flue surface and should be looked upon as of no value at all. The bottom of a fire is seldom in a state to heat a surface several inches below it at all effectively, and remembering that this surface almost always has a layer of ash upon it, the result, in heating effectiveness is not worth counting. Briefly, therefore, direct surface is confined to that horizontally over the fire, or vertical, or any degree between these two, but beneath the fire it should be given no heating value at all. A water-way beneath the fire serves an excellent purpose, as will be learned, but not as heating surface.

Indirect heating surface is that which the fire does not shine upon, and which receives no heat by radiation from or

by contact with the glowing fuel. Indirect surface is flue surface, and is heated wholly by flame, and the heated gases of which the products of combustion are composed. With coke fuel, which is so largely used, or anthracite, which is the finest fuel known (if the quality is good), there are no flames, and the flue surface is heated by hot but non-luminous and invisible gases, i.e. products of combustion. Flame gives abundant evidence of two peculiar phenomena that have to be considered in boiler construction, and heated gases show the presence of like results also. Flame affords little or no heat, unless it has actual contact with the surface or substance which is to be heated by it. Anyone can obtain the most obvious proof of this with a small flame from a fire, or a gas flame, for the hand can be held quite close at the side of such a flame without feeling the heat at all painfully, but immediately the hand and flame come in contact, however little, the heat has an immediate intense effect. Flame, therefore, must have contact to be effective.

The other phenomenon peculiar to flames and heated gases is that they show a positive objection to having contact with surfaces cooler than themselves. If possible, which means if there is room, or the draught and formation of the flues admit of it, flame and gases will float and travel between surfaces without having contact with them. Flues have, therefore, to be of suitable sizes as to shape and smallness, yet not so small as to choke the draught, and have an ill effect on the general work of the boiler.

Although flame is more effective in heating than hot gases, yet the difference is not so very great, for both proceed from an equally hot source, in fact the gases in many cases come from incandescent fuel, while flames are evolved when the fuel is at a less temperature; but flames really represent a portion of the fuel still in a state of combustion, and this gives them a greater heating value than gases. Opposed to this is the fact that flames deposit soot which gases do not. Soot is a poor heat conductor, and a very thin coat will cause flame to have no better heating effect than gases have on a clean surface. It is not intended to say that coke and anthracite pro-

duce no dirt in the flues, for they do, and the flues must be regularly cleaned, the surfaces being well brushed with a stiff *wire* brush, but the fouling of flues by non-bituminous fuels is much less than with a bituminous fuel (ordinary coal), and on this account and for general reasons the indirect surface is counted as of one heating value whatever fuel is used.

While on the subject of contact between flames with surfaces cooler than themselves, reference may be made to a paper read by the late Thomas Fletcher, as long ago as 1886, and which, while showing how better results could be obtained, does not appear to have been put to the practical use it might have been. Makers of cast boilers might with advantage give consideration to it; it is not so easily applicable to wrought boilers. It is not necessary to give the paper *in extenso*, as the substance of it may be explained quite briefly. From a series of experiments and observations, it was found that when flame is applied to heat a vessel of water, the flame does not have actual contact with the metal of which the vessel is composed. This is shown to be due to the fact that the metal, by reason of its having water in contact, can never be of a temperature equal to that of the flame itself nor near it. It matters not how hot the water may be, it is still far below the heat of the flame, and it follows that when the vessel contains cold water the conditions and results are still worse.

There appears to be a film of air, or a space, between the flame and the metal, and while this exists the results are distinctly less satisfactory than when a more perfect contact is obtained. The purpose of the paper was to show how the film or space could be disposed of, and more effective heating obtained. What appeared to be necessary was some provision or means by which the metal of the water vessel could be made to more nearly approach the temperature of the flame; for, as will be understood, flame has better, if not perfect, contact with surfaces at much higher temperatures; and when this contact is obtained, the good results noticed are quite out of ratio with the increase of temperature. In other words, there is the difference that might be expected between imperfect and perfect contact.

To obtain the desired effect a vessel was made, in the form of a kettle, with a large number of pins or *solid* projections on the bottom, as Fig. 61*a*. These were of copper, practically indestructible by heat, and possessing good heat conducting properties. The advantage gained by this arrangement was that the pins (about 1½ inch long) had their lower extremities too far removed from the cooling effect of the water to be kept at a low temperature, consequently they became highly heated and nearer the temperature of the flame. This being so, the flame had a more perfect contact, and parted with its heat more freely than it is ready to do to a cooler surface, and the result was that 40 ounces of water was boiled in one minute fifty seconds, whereas with a kettle of similar size, with a plain bottom, the same quantity of water took three minutes fifty seconds, or double the time.

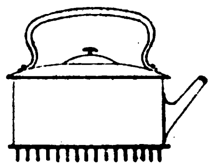


FIG. 61A.

It is worthy of note that this idea was promoted very many years ago, with a view to increasing the efficacy of boilers, but the gain in effectiveness that was claimed had its origin in a quite different idea. It had been found, and is still recognised, that the water in a boiler can take up, i.e. absorb, heat over two and a half times (2·6 times) as fast as a given area of plain heating surface can convey it from the fire, and that, therefore, the water on one side of a plain boiler plate never receives one half the heat it is capable of taking, however hot the fire and plate may be. The idea of using projecting solid parts (it was solid flanges or gills in this case) was to offer an increased surface to the fire, of, approximately, two and a half times the metal heat-receiving surface to what the water contact surface was. Thus one foot of water surface would have about two and a half feet of heat-receiving metallic surface to supply it, and by this plan a considerable increase in results was hoped for. It was not expected that any particular economy in fuel would be effected, but that a small boiler could be given the effectiveness of a larger one at a very small extra outlay on the cost of the small one.

It will be seen, therefore, that solid projections on the

heating surface of a boiler would have two quite distinct good effects. First, the securing of a perfect flame contact; second, the increase of heating surface. The latter, it will be seen, would be actually of greater effectiveness than an equal increase of ordinary surface which has water close against it.

The writer's table of work values for heating surfaces in boilers, and which he first gave in his editions of "Hood on Warming Buildings," is as follows; and although its original compilation occurred some years ago there has appeared no reason or arguments since to require an alteration to be made:—

TABLE OF WORK VALUES OF HEATING SURFACES IN BOILERS.

DIRECT HEATING SURFACE.	
All that which faces the fire and receives heat by radiation from, and by contact with, the glowing fuel	One square foot will heat 30 square feet of radiating surface.
INDIRECT HEATING SURFACE.	
Primary flue surface: that is, flues which receive flame and heat immediately on leaving the fire box, and which may be termed first flues	One square foot will heat 12 square feet of radiating surface.
Secondary flue surface: that is, flues which receive flame and heat after it leaves the first flues	One square foot will heat 7 square feet of radiating surface.

Note.—The above figures only apply to the average, or the aggregate, of the surfaces which are either horizontal and over the source of heat, or are vertical, and receive the heat at the sides. Surface, whether direct or indirect, if beneath the source of heat, should not be included, as it cannot be given any useful value.

The above figures can only apply when the area of furnace bars is correct, i.e. not less than the area that is needed.

No allowance has been made for third flues. These occasionally appear when a chimney is high enough to admit

of such a boiler (prepared for them) to be used. With a draught such as would carry a useful degree of heat to a third flue the other surfaces might be given a greater working value, but the total result would be a greater consumption of fuel than is customary. The tendency now is to work all boilers with a slow draught, and for all ordinary purposes the figures given in the table will be found to apply correctly, ignoring the possibility of boilers with third flues.

Following on this subject of working values of boiler surfaces may come the question of deciding what size of boiler to allow and order for any given job. As to the design or pattern of the boiler, this may be judged by the description given with the examples in the following pages, and the purpose of this present paragraph is to discuss the question of deciding the best size, i.e. the power of the boiler, to be ordered.

Although the table just given has been compiled to show the working values of surfaces,* it is not customary for a heating engineer to specify the surface he needs in a boiler, nor to measure it up, or even to ask the manufacturer what surface a certain number or size of boiler has. Nor do makers give this information in their catalogues, though they might with advantage do so. There is no occasion for mystery about it, as catalogue working values are all based on surface measurement.

What has particularly to be pointed out is, that when a heating job is obtained and the boiler about to be ordered, it is necessary to first see what area of radiator or pipe surface has to be put in, then add the surface of all main or branch pipes which are not covered—well covered—to prevent loss of heat; and on arriving at this total of heat-losing surface there must be at least 25 per cent. added to find the catalogue size of the boiler to be ordered. Thus, if the total heat-losing surface is 600 square feet a 750-foot boiler must be ordered as the least size, while 800 feet (the addition of one-

* This table was compiled at the time that boiler manufacturers gave what were known as "theoretical," or "estimated," values to the different boilers that were shown in their catalogues, and not the "actual" values that now appear.

third) will be better for general good results. The writer quite commonly adds 50 per cent., which means ordering a 900-foot boiler for 600 feet of heat-losing surface, when the price of the job will admit. This, however, need not be considered a requisite or even a common practice, as the addition of one-fourth or one-third should meet all usual requirements and give satisfaction. The fact is that when an engineer has studied and practised his work for some years, he discovers that a reputation for unfailing good results can almost be built up on using boilers of full power. They are quick, work with an extremely slow draught, may be stoked carelessly or unskilfully, and prove distinctly economical. A boiler of bare power, even with a perfectly designed apparatus, will give poor results in many ways, results which are totally absent with a boiler of full power, and the latter will work in a way that one engineer describes by the word "sweet." In the writer's own house the boiler, one which has a proper catalogue rating, is 75 per cent. above power, that is its catalogue power is three-fourths more than the actual heat-losing surface. The consequence is that after filling the fire-box with coke, closing the draught-damper and opening the check-damper, the fire will go for sixteen hours and keep the water at 130° all the time. What this means is that the boiler only needs attention morning and night in moderately cold weather and is ready to give smart results directly the coldest weather comes, and it will do this with the draught-damper open only half-an-inch and the check-damper still half open. The general effect is a greatly appreciated economy in fuel and attention, while the apparatus generally works as perfectly as a horse with a master hand at the reins. It does seem as if a boiler of full power had some kind of mastery over many irritating results that appear with a boiler of bare power.

Although a heating engineer may have no direct interest in the question of fuel consumption, yet he indirectly aids his business if economy in fuel is coupled with good results, and this is what a boiler of proper proportions ensures. If a radiator can be given its required temperature with a slow fire (in the coldest weather), the economy compared to having to

keep a fast fire to get the same results is most marked. It is more than this for it is almost astonishing. The explanation that can be offered is that while a small surface in a boiler subjected to a fierce fire probably absorbs about the same number of heat units as a large surface subjected to a low heat, there is a truly vast difference in the number of units that go up the chimney; while in the hands of an attendant unskilled in stoking the fast fire can be made more wasteful than a slow fire. Such an attendant would not keep thin bright fires to get the best possible value from the fuel that a fast fire can give; he would more likely fill the furnace with fuel, arrange the dampers for a full draught and remember that he must return in an hour to put more fuel on.

It is necessary to again repeat that the addition of one-fourth or one-third to catalogue boiler powers will, or should, give every satisfaction in the ordinary way, but if there is the money to spend, a customer can be given a certain amount of extra satisfaction by increasing the boiler power a little more, and the engineer will most probably derive a certain degree of good advertisement by doing this. What has to be explained now is why any addition to catalogue powers is necessary if these powers are "actual" as the catalogues say.

As near as the writer is able to say, all makers' catalogues of ten to twelve years ago gave theoretical or estimated heating values to their boilers, these values being based on Hood's original work on warming buildings, in which he fixed the standard at one foot of direct boiler surface to 50 feet of 4-inch pipe, and one foot of indirect surface to 17 feet of 4-inch pipe. A foot length of 4-inch pipe being 1·17 square foot of surface, it will be seen how greatly in error the figures were for practical purposes. At about the time stated the boiler makers determined to abandon these values and substitute those which now appear and are termed "actual." It is not intended to dispute their being actual, for these new values represent what the boiler can actually do under best test conditions as to stoking and attention, with the minimum of heat loss, etc., and the makers are therefore justified in calling this the actual capacity. What

the engineer has to realise is that best test conditions are seldom the lot that falls to his boilers in practice, and this is precisely what he has to allow for. In so many cases, in residence work always, the conditions as to stoking and attention are more or less bad, the attendant, male or female, being unskilled and doing whatever amounts to being the least trouble. Perhaps this can be summed up by saying that test conditions chiefly mean a moderately thin fire in a glowing state, the work of a good stoker with fairly frequent attention; while actual conditions are represented by a mass of fuel shovelled on to last as long as possible. In the latter case quite one half of the heating surface has black fuel facing it for considerable periods. Finally, the majority of boilers are required to have their fires kept alight and the water moderately hot for seven to ten night hours, a requirement needing a boiler larger than one which heats the pipes only under test conditions. In certain cases, as in large business premises, where an engineer is kept for the electric light plant, hydraulic apparatus, etc., boilers may be put in with less margin for bad conditions, but, as already stated, if a little extra money can be spent it is well devoted to the boiler.

In regard to the most suitable area of fire-bars * for boilers, it may be explained that an insufficient area means an insufficient supply of air needed for combustion, while too great an area means, possibly, an unnecessary consumption of fuel. Neither conclusion is strictly correct, however, but there is no doubt that a boiler must have a certain area of bars to give best results when the fire is required to burn briskly; but too great an area of bars does not cause a waste of fuel unless the damper is not regulated, and the fire is allowed to burn too rapidly. A large area of bars does not allow of the passage of a large volume of air, unless the damper is opened sufficiently to admit of this; therefore, if an error is to be made, it is best to make it on the side of too great an area rather than too small. It is necessary to speak in this manner as no precise rule exists or can be made to

* Area of fire bars includes the bars and the spaces between the bars.

give the exact area of bars needed by all makes and sizes of boilers. Makers of independent boilers—boilers which have the bars sent as part of their structure—may be relied on to send what is best, but it is doubtful whether anyone could say the bars sent were of a precisely correct area. What is doubtless done is to estimate the correct area by tables or experience, or both, and then add a little to it to be on the safe side.

It is only with brick-set boilers that the heating engineer may have to choose the area of fire-bars he will use, as all independent boilers are provided with these and sent out complete, by the maker. The table which follows is therefore very brief, as it can refer only to the saddle boiler and boilers of somewhat similar character; and, it may be added, every boiler maker is prepared to send, with boilers of these kinds, a set of bars and furnace fittings, of suitable size, if he is asked to do so. The area of furnace bars is therefore, at this date, more a subject for boiler makers than boiler users.

AREA OF FURNACE BARS REQUIRED BY BOILERS FOR EACH 100 FEET OF RADIATING SURFACE.*

	Square inches.
With a plain saddle boiler . . .	50
With a saddle boiler having one check or water-way end	46
With a saddle boiler having two water-way ends and a tubular flue . . .	40
With a saddle boiler having two water-way ends and return tubular flues . .	35
With boilers as above but having cross tubes, *reduce* the area for each cross tube .	5 to 10

The foregoing areas will be found to exceed those of the bars which appear in modern wrought-iron boilers of powerful character, or the cast-iron sectional boilers. There are two reasons for this; one being the large area of heating surface within a small compass; the other, the greater height of chimney and keener draught usually associated with these boilers. About 20 to 25 inches per 100 feet is usual.

* The areas given include the bars and spaces between the bars.

The areas given are not intended to apply to boilers below 400-foot size. With boilers of the "Star" type, ranging down to 65-foot capacity the area must be larger, and the same applies to small saddle boilers.

The following are details relating to boilers, or the choice of boilers, which may be given here.

The desirability of choosing a boiler of full power has been explained.

For small works, of three or four radiators, the "Star" type of upright independent boiler may best be used, for they are cheap, and require no brickwork fixing. This boiler, however, after choosing one of full power, holds a comparatively small bulk of fuel, and if required to keep the water hot through the night without attention, should have a fuel hopper. Makers' catalogues show these.

The saddle type of boiler is not intended to bear pressure, and should not be put to an apparatus in which the cold cistern is more than about 25 feet above the boiler. For works in which a greater water pressure will be felt, a circular, i.e. cylindrical, shape of wrought-iron boiler must be used, or a cast-iron boiler (of any pattern).

For horticultural work the saddle boiler, or boilers of this type, do good service, as they are fully understood by gardeners; but in all glass-house work the gardener must be consulted as to the boiler to be installed.

In horticultural work it is not uncommonly found that the boiler pit cannot be sunk to a full usual depth, owing to surface water appearing. In such cases the deepening of a pit, and then making it water-tight, is an expensive task, and sometimes barely possible. To obviate the difficulty special makes of boilers can be had, designed for "shallow-drainage" as it is called. Examples of these are given later in this chapter.

For greenhouse work on a limited scale the Loughborough type of boiler can be used with great advantage, as no pit need be made to receive the boiler.

All boilers which are fed with water of doubtful purity—and this includes most horticultural boilers, which have their

water dipped from a rain-water tub, or a pond or ditch—should have mud-holes for flushing out the sedimentary dirt that must collect in the low parts of the boiler. Fig. 62 shows how these are best arranged with a brick-set boiler, the holes having pieces of 1¼-inch or 1½-inch tube screwed into them, these tubes coming through the front brickwork. A cane can then be inserted to disturb the sediment or mud, which is afterwards flushed out. The tubes, of course, have their ends capped off when the apparatus has water in it.

For heating buildings and places which are only warmed as required for use, and not every day (as churches, assembly rooms, etc.), a boiler known to have rapid heating qualities is the best to use. The saddle boiler is the reverse of this, while

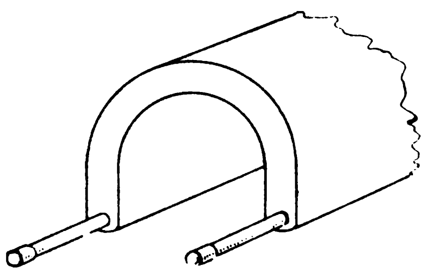


FIG. 62.

boilers having a large heating surface in a small compass usually fulfil the requirement successfully.

The independent boiler is, in a very general sense, preferable to a brick-set boiler, although its exterior cannot be used as heating surface.* Independent boilers are compact as to shape and size, take little room and require little fixing; and those now appearing in the makers' catalogues leave nothing to be desired as to effectiveness, without the need of using the exterior of the boiler as heating surface. Their first cost is certainly higher than a brick-set boiler, for a given power, but this difference is greatly reduced, if not extinguished in some cases, when the cost of fixing is compared.

* The outsides of all independent boilers should be covered with composition to prevent loss of heat.

What may be termed plain boilers should be only used when it is known that the draught is sluggish or will be suitably regulated. The saddle boiler is one, but a more pronounced instance is the upright cylindrical dome-top boiler, and its varieties, which are largely used. These consist of a plain upright shell, holding the fuel, with a flue nozzle at the top. Anything approaching a full draught will cause more heat units to go up the chimney than are absorbed by the water, and although such boilers may do the work they are said to do, equally with other makes, there is a strong likelihood that it will be done with an extravagant consumption of fuel. This is the ever-present doubtful feature in boilers—the fuel consumption for given results. One maker has claimed to get 92 per cent. of the heat units from the fuel into the water, while another authority considers 80 per cent. a full return. From this the percentage figures, as appear in papers read by able men, drop to 30 per cent., but in this latter extreme case it was the result of a test purposely made with fast combustion. Very little can be recommended as a remedy for this state of things except to say that, a plain boiler may be chosen when the draught is poor, and a flued boiler, with full interior surface (direct and indirect), when it is anticipated that combustion will be effected with a good draught.

Examples of Boilers.

BRICK-SET BOILERS.

The best known example of a brick-set boiler is the "Saddle," as Fig. 63. This is about the cheapest form of boiler we have, and it approaches nearest to what was once considered an ideal shape for a boiler, viz. a basin inverted over a fire. This ideal must be modified now, owing to the comparatively immense amount of heating surface that has to be got into a limited space; but for many purposes the saddle is still in demand, and does good service. Horticultural work takes most of them, as they are well adapted for low chimneys and a slow draught; and the average gardener or his assistant

knows how to bank the fire up, and get the best results from them generally. Being of horizontal shape, they do not need a deep pit, and, in the majority of cases, surface water does not interfere with their use. This boiler will not bear pressure well, and should not be used when the pressure exceeds 25 feet head of water. This, of course, does not happen in glass-house work.

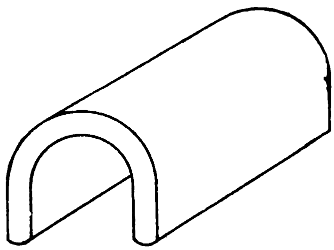


FIG. 63.

It is a slow-heating boiler compared to the more modern designs, not that its surface shows reluctance in taking up heat, but because anything like a brisk fire leads to an excess of heat getting away without doing service. On this account it will be found that there are many purposes to which the saddle boiler is put with very poor results. Probably the heating of places of worship is the most noticeable instance. It is the common practice still, in provincial districts, to use the saddle boiler and 4-inch pipes for this work, a combination which gives the worst results in church work (see page 87). In all places where quick results—a quick response to the fire—are needed, then the saddle boiler should be avoided; but where the reverse of this applies, as in all horticultural and glasshouse work, the saddle boiler does good service.

The plain saddle boiler is best not put to heat more than about 800 to 1000 feet of 4-inch pipe, as a boiler of greater length than 5 feet cannot be worked to advantage unless it is of a much more powerful character and greater fuel consumption. In large horticultural works, the saddle boiler, when used, is put to heat a comparatively small quantity of pipe, the work being allotted in sets of houses, two, three or four houses (according to size) to each boiler. In such cases a large area of ground covered with glass quite bristles with low chimneys. In other cases the more powerful flued type of saddle is used, this working satisfactorily up to nearer 2000 feet, but the writer learns that some large growers, par-

ticularly in the north of England, are using the most powerful sectional boilers, heating about 5000 feet of 4-inch pipe from each boiler.

The customary method of fixing the saddle boiler can be described from Figs. 64, 65, 66 and 67, the process being as follows: The brickwork base is first built up at sides and back to the level of the fire bars, the dead-plate and bearing-bar (for the fire bars) being then fixed in place. The height of this base will be according to the furnace-front (Fig. 67), it

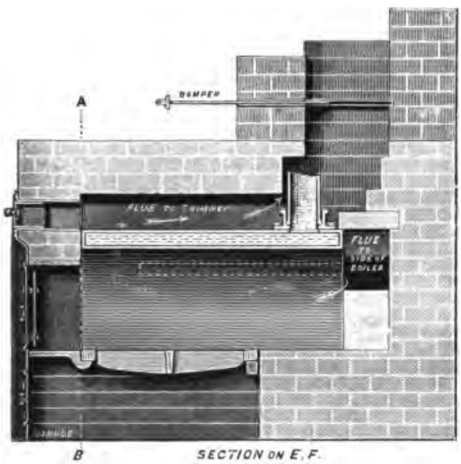


Fig. 64.

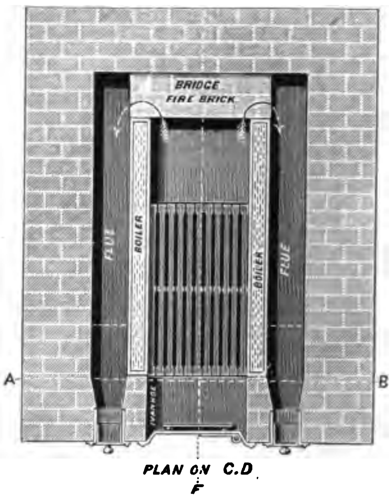


Fig. 65.

being arranged that the dead-plate comes just about level with the lower edge of the furnace door.* The space between the brickwork base, and which forms the ash pit, is made the same width as the interior of the boiler, and about two-thirds its length (the length of the bars and dead-plate combined). The boiler is then placed in position, and the pipe connections made.

It will be seen that with the brickwork which follows, the

* Instances occur in which the dead plate is made to slope down from the furnace front to the fire bars, it being possible by this plan to save an inch or two in the depth of the boiler pit, though it reduces the height of the ash pit.

boiler is arranged to come tight against that in front, while a flue space is left at each side and at the rear end. The side flues vary from 3½ inches to 5 inches in width according to size of boiler, while the end flue is from 5 inches to 7 inches. The illustrations, it must be mentioned, are not to scale, and no judgment must be formed by comparing the parts or spaces shown in them.

Before throwing the arch over the boiler, to form the flue space, it may be necessary to first put in the brickwork "bridge" shown at the back of the boiler. This is usually built of fire-brick, reaching about half-way up the end of the

FIG. 66.

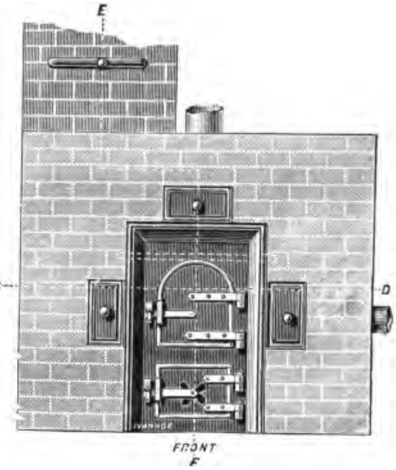


FIG. 67.

boiler, as shown, but not so high as to come nearly level with the midfeathers. It forms a boundary to the fire-box to prevent cinders and ashes from working into the flues, and tends to throw the flame up against the crown of the boiler. Above this another bridge has to be made, to prevent the flames taking a short cut to the chimney, instead of passing through the horizontal flues. This will be seen in the form of a fire-brick resting on the top of the boiler (at the rear end), but more often it is a row of bricks, as Fig. 68 or 69, or occasionally a solid fire-brick lump is used, as Fig. 70.

Fig. 68 is not a good plan, as the iron bar will probably fail and collapse at too early a date, and the brick arch, as Fig. 69, is more to be commended. This arch can rest on the mid-feathers, if preferred, but in this case the midfeathers should rest on at least one or more bricks gathered out from the back wall.

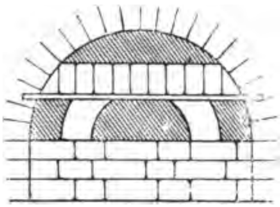


FIG. 68.

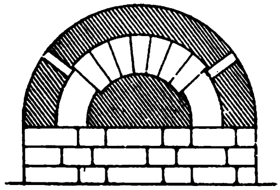


FIG. 69.

Having arranged for the provision of the bridges, the arch can be thrown over the boiler, the midfeathers being provided at the points shown. There is a simple way of doing this. The brickwork can be carried up as far as the midfeathers

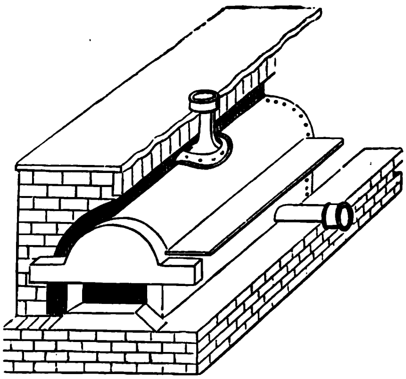


FIG. 70.

without difficulty, and from here it can be laid on a bed of sand or ashes. The sand or ashes are strewn on top of the boiler until, when lightly patted down, there is a thickness equal to what the flue is to be. The bricks are then laid on

this, and the work completed, and after all is dry or set the sand or ashes can be raked out.

Three flue-cleaning doors are necessary, as Fig. 67 shows, and as appear in two of the other illustrations. The two lower ones come level with the bottom of the side flues, so as to facilitate scraping out all soot or dirt, and the upper one comes centrally over the boiler. This latter, however, though usual, does not admit of the soot or débris, which settles and heaps itself on the midfeathers, being disturbed.

In fixing the furnace-front, difficulty is often experienced in getting it to remain tight against the front brickwork. Ordinary cramps are not effectual for long, nor does the brickwork always remain in good condition. The only satisfactory method is to have two long rod cramps made to reach from the furnace-front to the rear end of the boiler, one on each side. Let one end (of each cramp) clip round the rear end of the boiler, while the front end comes through the furnace-front, and is threaded so as to be tightened up with a nut. They are really long bolts, nutted at one end as usual, but with hooks at the other ends where they usually have heads.

The doubt that enters into the rather elaborate fixing of a saddle boiler is whether the indirect or flue surface of these boilers is scarcely worth the trouble. The two side flues, which first receive the heat that leaves the fire, are of some value, but the fact that only one side of these flues is heating surface reduces the usefulness of the fixing. The flue over the top of the boiler is practically useless, for surface beneath the source of heat, especially in a second flue, cannot be worth the trouble of throwing an arch over to get it. The arch, however, is necessary to make a return for the side flues, and this brings forward the question why boiler makers have not made this type of boiler more square, as Fig. 71. With this

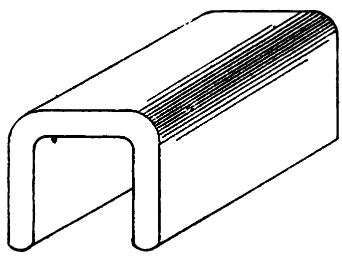


FIG. 71.

no arch would be needed, and the fixing would be very simple. The brickwork could come tight down on top of the boiler, and the sides could be used for first and second flues by placing the midfeather halfway up each side. These side surfaces, too, for the second flues, would have some better value than a flue across the top; and, lastly, this shape of boiler gives a greater direct surface, facing the fire, for a given length and width. It is peculiar to note that nearly all the more powerful relatives of the saddle boiler, those with internal flues, etc., are of a more square shape, and are not arranged for top flues, although external side flues are sometimes arranged for.

A different method that can be recommended for fixing small-sized saddle boilers is illustrated in Figs. 72 and 73

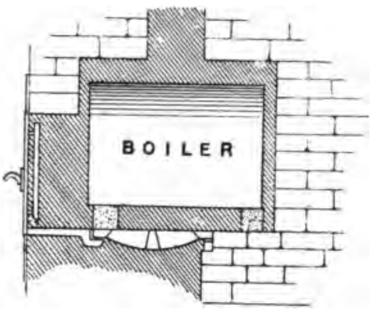


FIG. 72.

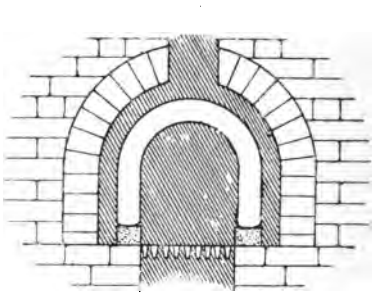


FIG. 73.

The brickwork is much the same as in the preceding example, except at the front and rear ends; and it will be seen that the boiler is raised above the level of the furnace bars three inches, by standing it on fire-bricks at its four corners. The flame and heat largely pass under the lower sides of the boiler, and affords an effectual degree of heat to the outer surface. The exception is when the bottom of the fire is thick with ash, but even then some heat passes. The spaces between the front and rear ends of the boiler and the brickwork there, are about 1½ inch, these spaces carrying away the products of combustion from the crown of the arch, and allowing of a sufficient draught when the lower openings are

partially choked with ash. The front and rear 1½-inch flue-ways are arranged for a chimney coming centrally over the boiler, as shown. If the chimney came at the rear of the boiler the 1½-inch space there might be omitted, and a 2-inch space put in front only.

The writer has been told that a fault this method of fixing possesses is that it leads to the earlier destruction of the boiler if sedimentary dirt collects in it. The two lower edges, where the dirt must collect, come in the very hottest part of the fire, and it is well known that whenever there is a deposit of earthy mud in a boiler at such a point, the plate must become burnt, perished and fractured. It is not that the sediment does this of itself; it is that the deposit separates the plate from the water, and the plate, which then loses the

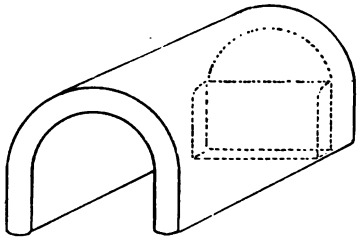


Fig. 74.

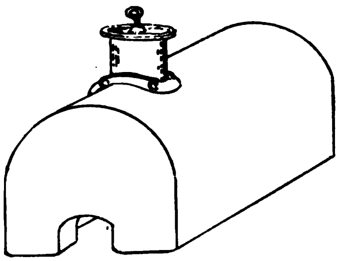


Fig. 75.

cooling influence of the water, is injured in the same way as it would be if the boiler had no water in it at all. Wrought iron is ill able to bear the heat and effects of a fire, if it does not have water in close contact on the other side of it. Cast iron is much more serviceable in this respect, this being the reason that wrought-iron boilers have cast-iron fire-bars and furnace fittings. The point in this case, however, is not as bad as it may sound, if ordinary care is used. The care to be exercised is to use only clean water, or to clean the boiler at regular periods.

An improvement on the plain saddle boiler which adds considerably to its effectiveness, is the "check-end," shown in Fig. 74. This provides a water-way bridge in place of the brickwork one shown in Fig. 66; while a water-way front, as

Fig. 75, adds still more to the heating surface and general efficiency. These two water-way ends begin to make the boiler appear like the inverted basin ideal, mentioned on page 160, and for slow draught it becomes a good boiler. When, however, a boiler has a water-way front it becomes necessary to provide it with a top feeder, as shown, through which the fuel is put as required. The brickwork at the top of the boiler is then usually slabbed over with stone, and the fuel for feeding piled there. The attendant then only goes to the front of the fire when the bars require clearing, the ash removed, etc.

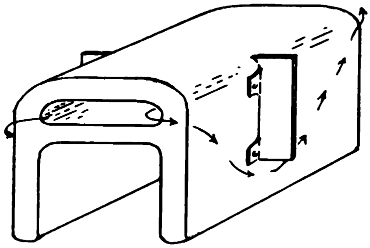


FIG. 76.

An increase of power of a practical kind is obtained in a flued saddle boiler, as Fig. 76. In the fixing of this, the top surface is not used, the flame, after passing through the flue

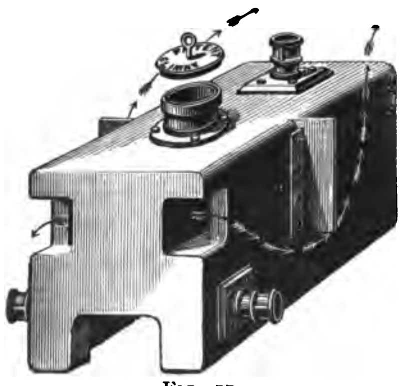


FIG. 77.

from back to front, passing along each side under the vertical feathers shown.

A boiler possessing good features and a considerable demand is the "Climax," shown in Figs. 77 and 78. This amounts to being a saddle with two water-way ends and a

pair of flues through the crown. It is distinctly effectual, as may be readily judged, and is better suited for a normally good draught than the plain saddle is.

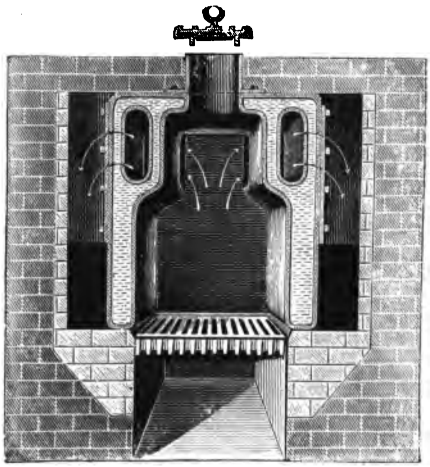


FIG. 78.

What the writer considers to be an even more effective arrangement of flues is that in the "Gold Medal" boiler, Fig. 79.* In this the whole of the flue surface is interior, and

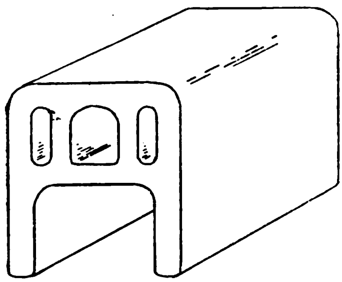


FIG. 79.

FIG. 80.

with a boiler of fair length the heat units which reach the chimney are a reasonable minimum. There is no need to use

* This boiler was awarded a gold medal by the Royal Horticultural Society, in open competition, at a show held in Birmingham.

the exterior of this boiler as heating surface, and no heat is devoted to heating brickwork.

Some of the foregoing boilers are considered to be better suited for "shallow-drainage" (shallow boiler-pits owing to the high level of surface water), more so than the saddle boiler, but this is chiefly due to their being of less general dimensions for a given power. A boiler that is specially designed for this trouble is Jenkins & Co.'s "Delta," Fig. 80. This, it will be seen, is a flued saddle boiler of no greater height than the lowest plain saddle boiler, as the flues are at the sides. The

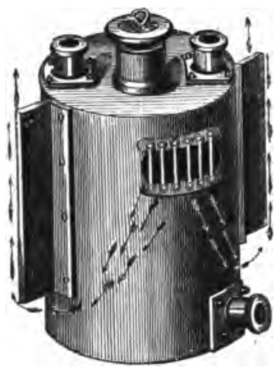


FIG. 81.

FIG. 82.

design of the rear of the boiler, too, is particularly good, as it amounts to giving the boiler a full water-way end and a water-way bridge within the end. The flame and heated products, when they leave the interior space, come forward along the side flues and then return to the rear along the two exterior sides of the boiler to the chimney. A top feeder can be put to this boiler, if desired.

There are now two forms of cylindrical brick-set boilers—boilers which will bear pressure, besides having other special features—which may be described. Figs. 81 and 82 represent the first of these, it being, again, the inverted basin mentioned on pages 160 and 168. The feeding door is at the top as shown, and the flames and gases, passing out of the barred opening, sweep down and over practically the

whole of the exterior surface. There is little or no surface which is not heated in this boiler, and all the surface is good for a brick-set boiler. The bars on the opening, through which the flames come from the interior, are provided to prevent fuel falling through and choking the flues.

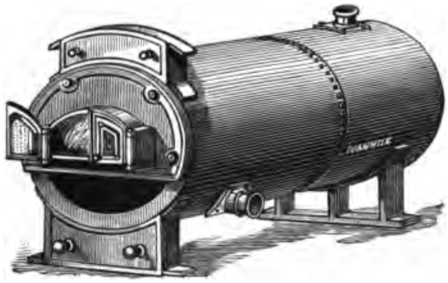


FIG. 83.

The other cylindrical brick-set boiler is the well-known Cornish "Trentham," Figs. 83 and 84. This has had, and still has, a good share of favour for large buildings, owing to its being of a fairly powerful character, and being capable of bear-

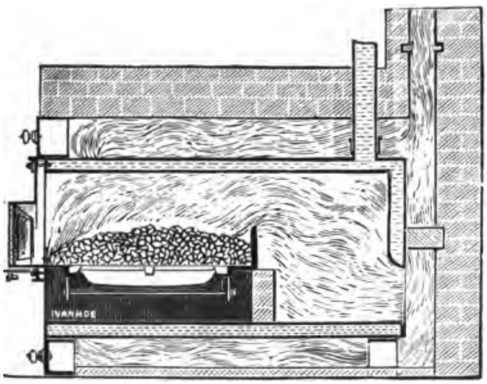


FIG. 84.

ing practically any pressure. The waterway carried below the fire-bars is a good feature when the water is of doubtful purity, as sediment can collect here and not cause any serious results. On the other hand, this boiler takes up a deal of

room compared to the more modern boilers of equal power, and it is to be feared that its rating is too liberal, as the surface beneath the fire bars has nothing like the working value that direct surface is allowed to have. It has been largely used for heating Board Schools, and buildings of similar character, but must be gradually losing ground by reason of the advantages possessed by the newer independent boilers.

The fixing of the Trentham boiler resembles the saddle, in some respects. The bridge, however, is brought within the boiler, this being necessary by the great length these boilers usually have, and this has the good effect of making a better contact between the flame and upper heating surface. On the flame leaving the boiler by the low opening at the rear, it is made to pass under the boiler, then up, and partly around the front part, and back along the sides and top. The plain kind of this boiler is a mere water-way tube, but results are greatly improved by the addition of a water-way end at the rear (as Fig. 84 shows), also by cross tubes and a water-way bridge. The latter is an oval cross-tube on edge, passing from side to side, and not connected to the bottom water-way. With these additions, and a moderate draught, practically as good results can be got without the external flues as with them, but not if the draught is keen and combustion at all rapid.

It is peculiar to note that manufacturers' illustrations usually show boilers—large ones, even such as the Trentham—with one pair of pipe connections only. The advantages of two or more connections, when they appear desirable, are given on page 62 and elsewhere.

Independent Boilers.

WROUGHT IRON.

The only thing that need be said as an introduction to independent boilers, in addition to what has been said, is that they should be covered to prevent loss of heat. The exterior is a heat-losing surface, not a heat-receiving surface, as with

a brick-set boiler, and as the boiler must have the hottest water in it the loss of heat must be the most rapid. It might be considered that for a given surface a boiler can part with a little more heat than the hottest radiator in a building, and as a boiler is often situated in a cold or draughty place the loss must be increased proportionately. Exception may be made with small boilers, yet the principle of preventing heat loss must apply to all. This subject is treated more fully on a later page.

The most ordinary type of small independent boiler we have is the "Star," illustrated by Fig. 85. This is an upright cylindrical water-way shell or tube, standing on a cast base, and surmounted by a cast top, as shown. It is made in sizes to heat 65 feet to 220 feet of radiating surface. It is also made with a fuel hopper on top, that a charge of fuel may be put in to last several hours without attention. This is a necessary addition, when the boiler is required to work with very little attention, for boilers of these small sizes cannot hold any quantity of fuel to speak of. This boiler is made quite vertical, as illustrated, or it can be had slightly conical. The latter pattern is intended to prevent the fuel "bridging" up, instead of falling gradually as the fuel nearer the bars is consumed.

Fig. 85.

The "Star" boiler, while being slightly the cheapest, is also the roughest in appearance; and a better design may be given in Robert Jenkins & Co.'s "Victor" boiler, Figs. 86 and 87. This is made in sizes from 80 feet to 380 feet of radiation, with or without fuel hopper, straight or taper sided. It will be noticed that this boiler has the return socket as low as possible, which is a convenience in some cases.

As stated there is a large variety of boilers which bear a close relationship to the preceding, some working up to about 700 feet of radiation, but it is not necessary to describe them here.

A boiler of small power, but possessing novel features, is Hartley and Sugden's "Sun" boiler, Fig. 88. It is made in sizes from 70 feet to 150 feet of radiation, and is particularly designed to take a charge of fuel to burn through the night without attention, and it can be made to work low horizontal circulations when required.

There are two special points worth discussion in this boiler. The first is as to whether a larger ratio of efficiency cannot be given per square foot of heating surface, when all

FIG. 86.

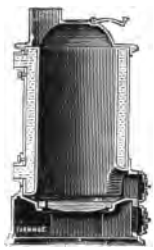


FIG. 87.

the surface lies immediately round the glowing fuel. With a cylindrical boiler of this diameter but double the height there would be double the internal surface, and it would be given double the work value; but, as upright boilers have usually a quantity of unburned black fuel in the upper part, no hesitation need be felt in saying that the double rating would be wrong. It is doubtful whether, with upright cylindrical boilers, the upper half has more than three-fourths the efficiency of the lower half, when the fire is wholly bright fuel; while, when the top of the boiler contains black fuel, the ratio must drop very greatly. Direct surface in boilers is given an average or mean heating value, but in the boiler now referred to the surface is wholly of the highest quality.

The other special feature is the position of the flue nozzle. There have been arguments as to whether it is advantageous to put the flue nozzle high or low in an upright shell boiler, those in favour of the former considering that greater heat can be obtained without increasing combustion. Combustion, in boilers, is the chemical combination of the carbon of coke or other fuel with the oxygen of the air which passes through the boiler (known as the draught). It is contended that when the air enters the mass of glowing fuel it cannot get

FIG. 88.

far, say 12 inches, without its oxygen being disposed of; and that beyond this distance combustion cannot occur, although fuel is there, because a supply of oxygen cannot get as far. Yet the fuel beyond this distance becomes hot, and is supposed to afford heat without combustion. It is a weak case, for two reasons. One is that combustion and heat are synonymous terms, for heat cannot be obtained (in furnaces) without combustion. It is quite true we can have a red fire

in which combustion appears to be almost stayed; but it will be found that the heat-giving properties of the fuel have been stayed also. A red condition in the fuel is no true indication of the rate of combustion. It cannot be supposed, however, that red-hot fuel can be in a state of non-combustion; but, from many experiments made, it is found to be possible, as stated, to have red fuel in which combustion is extremely slow, so slow that in the space of one hour no change in the fire can be observed. As already indicated, this condition is attended by an extremely feeble evolution of heat, and it is only convenient to keep a fire in this condition between the times of full heat being wanted, at night, for instance.

FIG. 89.

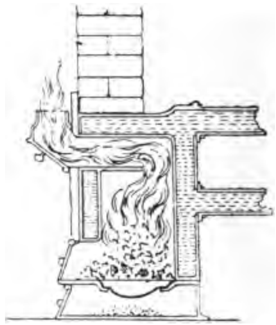


FIG. 90.

The other reason for the argument being weak is of a more complex character, yet just as sound, if not more so. When oxygen combines with carbon in proper proportions to effect combustion, the result is perfectly obtained and the product of combustion is carbonic acid (carbon dioxide, CO_2). If this gas has to pass through red fuel on its way to the chimney, it will pick up an atom of carbon and become carbonic oxide (carbon monoxide, CO), and this is accompanied by a loss of fuel and heat. This gas is combustible but not in a useful degree, and it can be seen on any thick coke fire burning as a feeble blue flame at the top. On this account, the low flue nozzle should give best results apart

from any other reason; and, disregarding this chemical reaction, the fire of a low nozzle boiler (the nozzle of reasonable lowness) will work quite as economically as one with a high nozzle.

Another small boiler with novel features is the type shown by Fig. 89, also by Fig. 43, page 94. This is made in powers ranging from about 90 feet to 600 feet of radiating surface. This boiler, while being capable of general work, is designed for fixing in the thickness of a wall as Fig. 90.

FIG. 91.

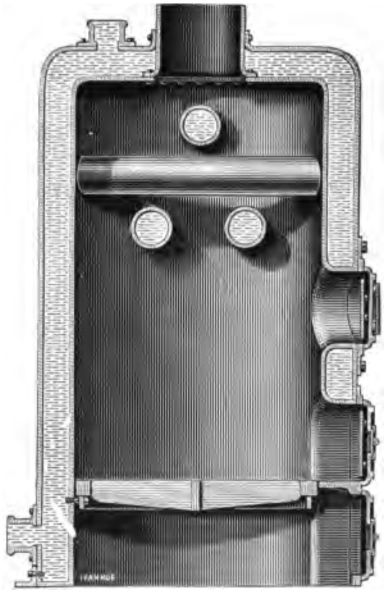


FIG. 92.

Usually it is the low brick wall of a glasshouse, and in such a position the cost and difficulties of a boiler pit are avoided. When so fixed it will be seen that the boiler front, with the feed door, furnace doors and smoke nozzle, all come outside the house, while the circular back part of the boiler and the pipe connections project inside. When possible it is a very convenient and cheap method of fixing, as can be readily seen. In some makes of this type the front has no water-way, it being considered best to have fire-brick behind the iron there

N

to resist the effects of bad weather and rain beating upon it. This boiler is referred to more fully on page 94.

A familiar boiler of the upright cylindrical kind is the "dome-top" as Fig. 91. This is a plain water-way shell with the water-way carried over the crown, making the top of a domed shape and giving the boiler its familiar name. It is made in powers from 120 feet to 1000 feet of radiation. Except for giving a top vertical connection for the flow pipe,

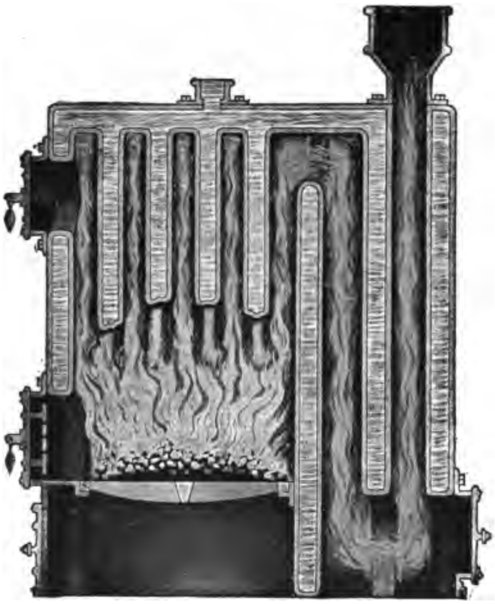


FIG. 93.

FIG. 94.

and having a little more heating surface than the other shell boilers noticed, there is nothing further to be described. It is a boiler that requires a slow draught, or careful regulation of the damper, to ensure economical results, but if it has this, the boiler has proved to be effective and worthy of continued use.

If the work is of fair extent and combustion occurs with a normal draught, then the dome-top boiler with cross tubes will be found more powerful and effective with a reasonable fuel consumption. Fig. 92 shows Robt. Jenkins & Co.'s

"Majestic" boiler of this type, and its sizes run from 1200 feet to 5100 feet of radiation. The latter size has as many as nine cross tubes of 8 inches diameter. This boiler is also recommended and used for supplying large quantities of hot water for bath and general tap supply, in hotels and institutions, hence the provision of the water-way carried below the

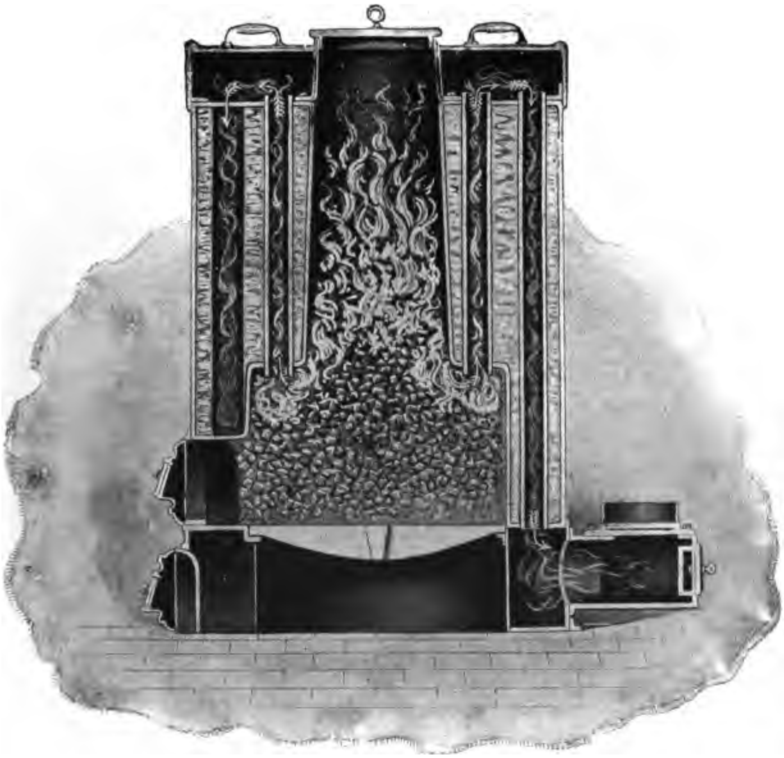


FIG. 95.

fire-bars. This affords a safe settling place for the lime deposit that is precipitated in hot-water supply work, when hard water is used. The outer dome shell can also be raised to make the boiler suited for steam generation.

During recent times there have been independent boilers designed and made of far greater power than anything hitherto attempted—for in the older catalogues it will be

found that boilers of high power were all of the brick-set kind, and it is reasonable to suppose that the introduction of sectional cast boilers from America proved a stimulus to the English makers. There are now many designs, showing ingenuity and a fine knowledge of boiler construction, but only representative examples can be given here.

Figs. 93 and 94 show Hartley & Sugden's independent "Eiffel" boiler, a boiler literally packed with heating surface, all of which may be considered of the best kind. Immediately a multiplication of direct surface is attempted it is found

FIG. 96.

to be essential that the internal circulation be studied. There must be provision for the water contained in the boiler to circulate, quite apart from that in the pipes which proceed from it and which may be supposed to be absent in this case; and it follows that the best internal circulation is obtained with vertical water-ways. Cross tubes do good work but vertical tubes, when possible and suitable, do better, and the same applies to any water-way in a boiler. This boiler is made in powers up to 3500 feet of 4-inch pipe. The feeding door is in front near the top.

Figs. 95 and 96 represent Lumby, Son & Wood's "Majestic" boiler. This may be described as an upright multitubular boiler, one in which a free draught may be permitted with the certainty of the best possible flame contact. All water-ways are vertical, while facility is given for top feeding. It will be noticed that access is afforded to the tubes, at top, for cleaning. Its powers range up to 3100 feet.

FIG. 97.

A final example may be given in Fig. 97, which is Kitchen and Co.'s "Severn" boiler. This combines the simplicity and efficiency of the dome-top boiler, with the addition of water-way tubes in the rear combustion chamber, so that a normal or a fast draught is admissible without loss of heat and fuel. It is a boiler that is finding considerable favour. Its sizes vary from 750 feet to 5500 feet of radiating surface.

Independent Boilers.

CAST IRON.

The desirability of covering these boilers is, of course, the same as with wrought-iron independent boilers (see page 172).

Cast iron boilers in large sizes are made in sections so that the boiler is built up by the hot-water fitter, the parts being bolted together. This is not necessary in the small sizes, but with boilers of considerable power and dimensions it has

Fig. 98.

advantages. One is that of ease of transport and handling. The boiler can be got into a basement and fixed up with a less number of hands than a boiler in one piece. The sectional construction, too, admits of a boiler being given an increase of power, when desired, by the addition of sections.

Perhaps the greatest gain in the use of cast iron is the extensive way in which the direct heating surface can be increased. With wrought boilers the surfaces have to be plain, whereas with cast iron they may be convoluted, ribbed,

studded, or made in any way that will ensure the best results for the fuel expended. Flues can easily be made and many variations of heating surface.

The writer is quite opposed to deprecating the wrought-iron boiler, for it has many good features, and is, so to speak, an old and faithful servant; but there can be no doubt that cast iron will withstand wear and tear better than wrought; and if the conditions are bad, by the collection of sediment and dirt, the cast boiler is much the more lasting of the two. With sectional boilers, too, a fracture is located to a section,

FIG. 99.

and this can be replaced without sending the boiler away for repair. The usually accepted opinion of cast iron, when applied to boilers, is that it is an untrustworthy metal, liable to crack, and faulty generally. This opinion must be based on the experience obtained with the side boilers of common quality kitchen ranges. Cast iron of reasonable quality gives excellent service whether water is on one side of it or not, but water must not be brought in contact when the iron is hot. Running water into empty or partially empty hot range boilers

is what has created a wide-spread idea that cast iron is an untrustworthy material.

Fig. 98 is the American Radiator Co.'s "Ideal Premier" hot-water boiler, made in sizes from 140 feet to 450 feet of radiation. The fire-pot (the part above the fire bars) is corrugated internally. The bars are of the rocking kind, which admit of the fire being cleared without the use of tools and without opening the fire or ash-pit doors. They are operated by an external handle. It is of a construction that might be likened to an improved dome-top boiler with increased heating surface.

FIG. 100.

Fig. 99 is the Beeston Foundry Co.'s small cast boiler, made to heat from 40 feet to 150 feet of 4-inch pipe, but, be it noted, this boiler, with modifications of its internal surface, is made to carry as much as 1050 feet of radiation. It is an improved form of box boiler, the first that has appeared in these pages, and bears some relationship to a perfected saddle boiler in an independent form. It is a good and effective form of heater, but like the saddle and the upright shell types of boiler, it must be worked with a moderately

slow draught to prove economical. This boiler, as will be seen, can be fixed in the thickness of a wall, as described on page 177, if desired, and can be furnished with end sockets for cast pipe.

Figs. 100 and 101 represent the College boiler,* a cast box boiler with corrugated fire-pot section, and three flues in the top section. The two side flues first receive the heat when it leaves the fire-box, and after coming to the front

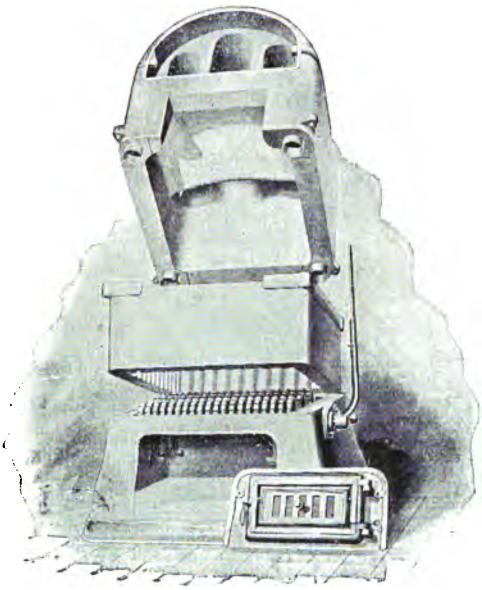


FIG. 101.

through these, it returns by the centre flue to the chimney. It is a highly effective boiler, working with a full or slow draught ; the bars are of the rocking kind. It is made to carry from 300 feet to 1600 feet of radiation.

Of boilers composed of upright sections, a first example may be given in Fig. 102, which is the Beeston Foundry Co.'s " Robin Hood " boiler. This has a corrugated fire-box,

* From the writer's catalogue.

with two horizontal internal flues, one above the other, at the top. The sections are joined by coned nipples, and held by the series of short bolts shown on the outside. Its sizes vary from five to twelve sections, capable of dealing with 700 feet to 2850 feet of radiation.

Fig. 103, which illustrates Hartley & Sugden's "White

FIG. 102.

Rose" boiler, is the newest design on the market at the present moment, and is peculiar in being the production of a large firm of wrought-iron boiler-makers, who have laid down an extensive plant for the manufacture of cast boilers. The sections are 6 inches wide, joined by coned (push) nipples, and held by short bolts externally, these bolts having right

and left hand threads. The heating powers range from 575 feet to 2500 feet of radiation.

In Fig. 104 is given an example of the American Radiator Co.'s manufactures, but as probably most readers know, the variety of boilers of the kind that this firm makes is considerable. This represents their latest type, the larger of the "C" series, capable of heating up to 6000 feet of radiation. It will be noticed that, starting down from the crown or top of the boiler, the first two rows of openings are flues,

Fig. 103.

as the sections at this point butt hard together, but the parts of the casting below, with openings resembling flues, are really direct heating surface, as there is clear space between the sections at this point. This lower part may be considered as a cross tube with tubular water-ways leading into it from below, and out of it above. The annular openings between the two lines of flues above admit of the boiler being worked with draughts of variable strength.

Fig. 105 shows Keith's "Challenge" boiler, a style of

construction differing from the preceding, in that the sections are placed the opposite way. The sections above the fire-pot much resemble gratings with water-way bars, and thus amount to being a series of cross-tubes. This makes it a very powerful boiler, capable of absorbing a full percentage of heat before it reaches the chimney.

A sectional boiler embracing a novel feature is Munzing's "Mercer" boiler, illustrated by Fig. 106. This is a box-shaped boiler with corrugated fire-pot and return flues through the upper part as shown. This is a good design of construc-

FIG. 104.

tion, giving excellent results with a normal or a full draught. The peculiar detail is in the fact that the sections have no direct connection, no nipple joints or communication of this kind. Each section is in reality an independent boiler, and is connected by short flow and return pipes (of suitable size) to the drums or headers shown. It is an efficient way of joining up the sections, but rather more expensive than the usual nipple coupling. The gain is realised (in certain, or in most cases) when repairs have to be effected. A boiler—when a water-way fractures, as it must do some day—always fails

at an inconvenient moment. It does not fail in the summer, when its services can be dispensed with, but, on the contrary, this trouble occurs when it is in use warming the building. With this boiler the fracture of a section means having the

FIG. 105.

fire out for a few hours only, as all that needs to be done is to run the water off, disconnect the section at the three points, plug the three holes in the drums or headers, and then turn the water on again. The fractured section is left in its place,

empty and dead, until it is convenient to replace it with a new one. The boiler with one dead section is thus made less efficient than before, but this is better than having the boiler wholly dead for a time.

A final example may be given in Keith's "Python" boiler, Fig. 107. This is quite a departure from those previously noticed, and at present may be considered the largest boiler,

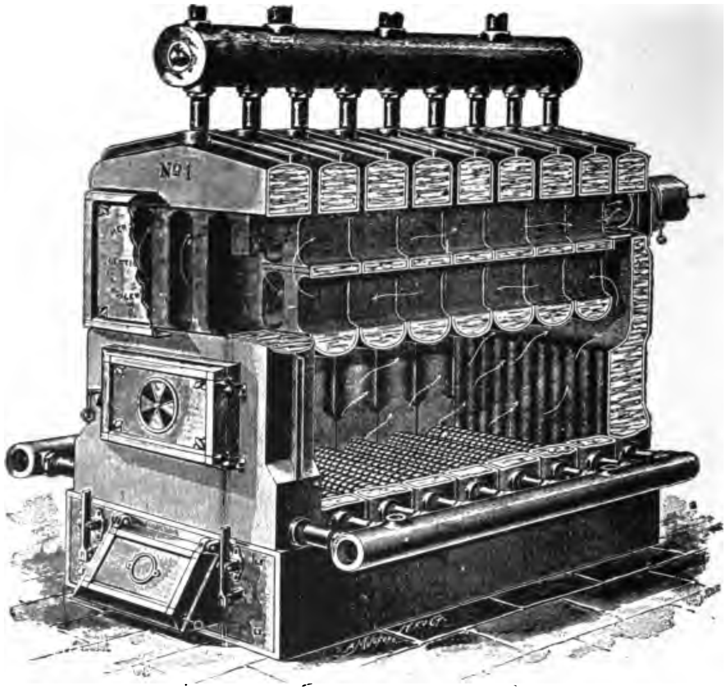


FIG. 106.

in point of power, that we have. It is a water-tube boiler, with corrugated water-way shell and only a glance is needed to show how effective the heat absorption must be.

It is almost unnecessary to explain that only representative boilers have been described here, in fact only a few makers are represented ; and it is desirable to say that both in design and make there are numberless other boilers which

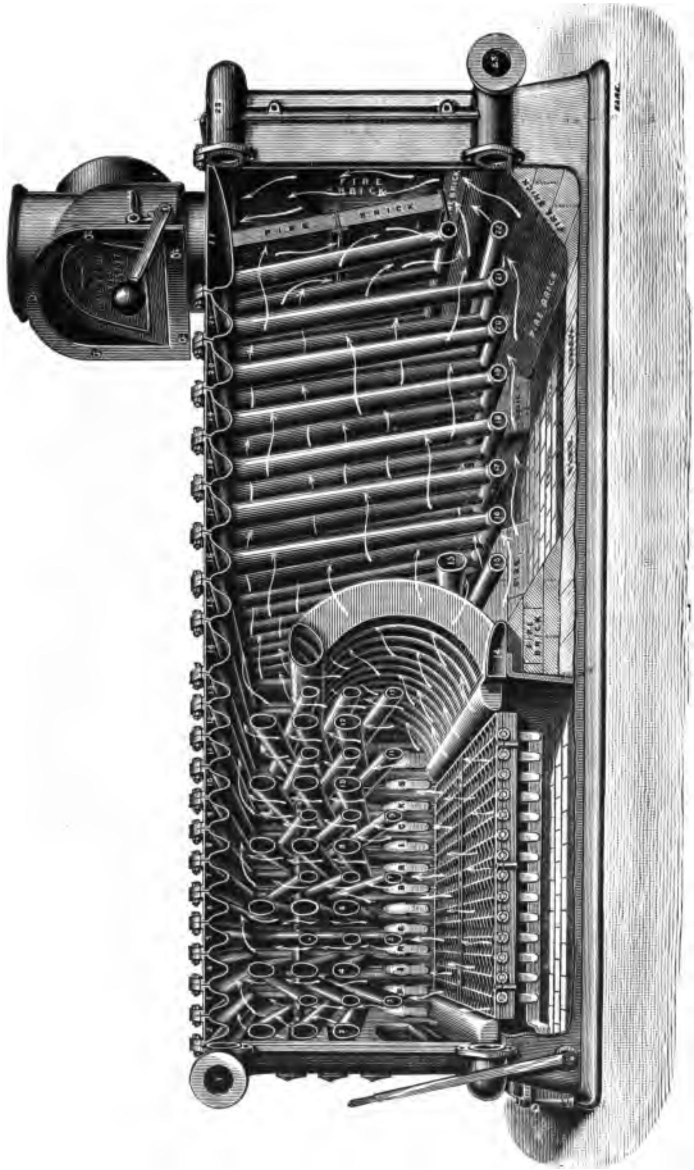


Fig. 107.

have excellent qualities, do good work, and are in large demand. It has been with no intentional neglect, and certainly conveys no want of appreciation, that other boilers have not been shown. It is that space will only admit of types and working principles being described as far as possible.

CHAPTER XIV.

RADIATORS, CAST PIPES AND FITTINGS, VALVES AND ACCESSORIES, PIPE JOINTS, ETC.

IT may be best to commence the subject of radiators by describing how they differ from the older pipe-coil—for both are a congregation of pipes—and show what improvements the former embodies.

The pipe-coil consisted of two upright box-ends, between which a number of horizontal pipes extended, either in a single row as Fig. 108, or in double or triple lines. This detail would be governed by the surface required or the size or shape of the space provided for the coil. The first fault possessed by the coil * as compared to the radiator is its size for a given area of surface or effectiveness. A coil as illustrated, to contain 50 feet of surface, would require to be about 7 feet long if the pipes were 4 inches; while, if 2-inch pipes were used, there would require to be double the number of pipes. The height would be about 40 inches; projection 7 inches. A radiator 30 inches long, 38 inches high and 7 inches projection has the same surface. Another fault is the appearance. Coils are so unsightly that in almost all exposed positions they have to be covered with a coil-case, and this introduces several faults of quite new kinds. First, there is the expense — for coil-cases are not cheap—the greater space occupied, the impossibility of cleaning the coil (for the parts of the case are *bolted* together), and the reduced heat diffusion occasioned by boxing the coil up. The hori-

* The term "coil" doubtless originated with the earlier practice of using siphon-ends to join the pipes, instead of box-ends, thus giving the whole an appearance of a length of pipe coiled to and fro.

zontal pipes of the coil lend themselves to the collection of dust and floating matter, and on taking down coil-cases the coils are commonly found loaded with dirt in a peculiarly matted state. Practically all the materials, of which this dirt is composed are poor conductors of heat—hair, cotton, wool, fibre, grit, etc.—and this is quite equivalent to wrapping the pipes in felt or cloth. Finally, the constant heating of this debris cannot be approved from a hygienic point of view, and it is possible, with enclosed coils, after a time, to have a faintly ill-smelling air rising from them.*

In stating the faulty qualities possessed by coils of horizontal pipes as compared with radiators, the improvement

FIG. 108.

effected by the introduction of the latter will be seen. A further advantage the radiator has been made to possess is in the area of its tubes. They are never round, and directly a more flattened form is used the area, which means the quantity of water held, is lessened without lessening the external surface. For a given surface a round tube holds more water than a tube of any other section, and although a large bulk of water is an advantage in horticultural heating (see pages 87 and 92), it has no good features in heating

* These remarks apply to practically the same extent with pipes in trenches, see p. 88.

buildings. A 4-inch pipe holds approximately two quarts per square foot of surface, a 2-inch pipe about one quart per foot, while the best quantity for radiators is considered to average 1½ pint to 1¾ pint per foot of surface. With this smaller quantity of water, more rapid results are obtained in heating the surface, the reason being that the bulk of water in the apparatus is less, and can be heated up more rapidly than a larger quantity. On the other hand, the larger the surface compared to the bulk of water the quicker the water must be cooled, but the average bulk-for-surface just given does not allow of the cooling being so rapid as to be a fault. To the best of the writer's belief the minimum in existence is 1 pint per foot, but this might be considered an extreme for satisfactory results; and in departing from the 1½ pint to 1¾ pint per foot standard it would be decidedly better to increase the quantity of water a little rather than decrease it.*

A few words may be said in regard to the appearance of radiators. In factories, many business places and the like, a plain or severe looking radiator may be used; while in hospitals and institutions of the kind the plainest possible radiators are intentionally used to facilitate cleaning, and offer no minute resting places for dust or micro-organisms. In such places appearances count for little; but in places which are occupied by pleasure seekers, or in shops and also, particularly, in homes, the ornamental radiator is in demand, and often fills a want. In residence work the radiators, even now, are not handsome enough. There can be no doubt that the radiator in all its forms has stimulated residence heating, and possibly the latter has stimulated the radiator manufacturer to make nice designs; but better can be done yet, although much good has already been effected. The possibilities in the direction of making radiators of beautiful design are enormous, for there is nothing to prevent their being made a handsome adjunct to the furniture of a room.

* If radiator tubes are clustered at all closely, they lose heat less rapidly, and the smaller bulk of water would then cool less quickly; but these tubes never should be clustered, if best results are desired, owing to the fact just stated that they do not so freely part with their heat, either to the air or by radiation.

What we now have in the way of radiators is, however, something to be thankful for. Without doubt the very existence of the radiator has increased the work of the heating engineer enormously, and it only needs a moment's thought to show what a state the trade would be in, if we had to revert to cast pipes and pipe-coils again.

Where a decorative radiator is required, the heating engineer should see that its appearance and general good effect are kept up, or improved, and not spoiled. The spoiling, when it is done, is in the painting. Broadly speaking, decorative radiators should be coloured in light tints, as light as possible, or in white. The latter is the writer's favourite paint, either matt or enamel, or one picked out with the other. On no account should the fitter's favourite colour, purple-brown, be used, nor deep green or any sombre colour. Although this subject can only be given a brief paragraph, for it is of no use repeating the advice, it is a really important subject, having a strong bearing on the approval and progress of the work. It must be remembered, that, except in buildings devoted to work, or in institutions, a lady's likes or dislikes have to be fully considered, and only dainty schemes of decoration will be approved. If talent is expended in the designs and handsome appearance of fireplaces, joinery work and wall decorations, why not on radiators? Failing this, the radiator may be a dull or ugly spot amidst handsome surroundings.

Radiator sections are now jointed by nipples, but these are of two kinds. The rubber joint or the composition collar no longer has any existence in this work, for they were considered liable to perish and give trouble.* The push or taper nipple, as Fig. 109, and the screw nipple, as Fig. 110, are used, and although the exclusive user of one has arguments against the other, there are large firms which use both. The push nipple is a piece of thin tube turned down slightly taper at each end, so that when it enters the corresponding holes in the radiator

* The writer put 72 rubber-jointed radiators into some large business premises about eleven years ago, just before the American radiator was pushed in this country, and up to this moment not a single joint has given trouble. The nipple joint is best, however.

sections, and the sections are drawn tightly together, a sound metal-to-metal joint results. The screw-nipple is tapped with a right-hand thread at one end and a left-hand thread at the other, so that when the ends are started in the radiator sections, and screwing up is commenced, the sections are drawn towards one another. The screwing up is done by a flat tool inserted inside the nipple, and engaging against the studs inside it. A wrench or tee head is put on the other end of this tool by which to turn it.

In either case it is possible for a fitter on the job to take out or insert a section in a radiator ; or a faulty section, if one is found, can be as easily replaced. The radiators having

FIG. 109.

FIG. 110.

push-nipple connections have bolts through from end to end to hold the sections tightly together ; this is not necessary when screw-nipples are used. The nipples are usually of cast malleable iron, this being found more lasting than wrought iron, particularly when the radiators are used for steam, and condense-water has contact with the nipples.

Those who use the screw-nipple exclusively consider it superior to the push-nipple, but the reason is not at all obvious. It will be found that the majority of cast sectional boilers are jointed with push-nipples, and if suited for this purpose they are surely suited for radiators. The only fault the writer has to find is that the push-nipple is rather light, and might be of heavier metal with advantage.

EXAMPLES OF RADIATORS.

It will be understood that, as with boilers, only types of radiators can be given here, and any make omitted may be as good as those shown, and its omission indicates nothing to the contrary.

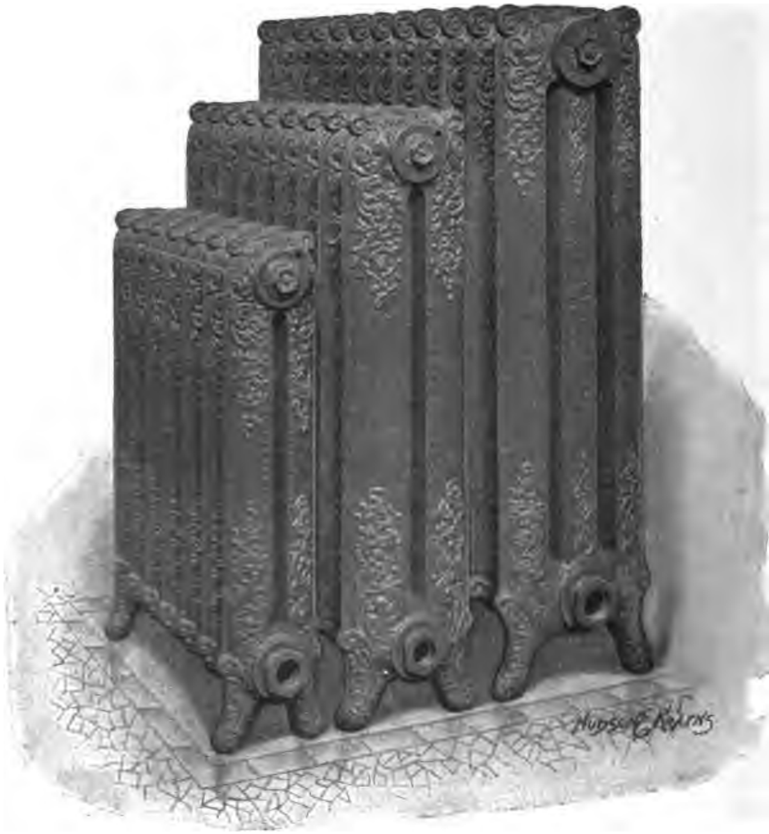


FIG. 111.

English Manufacture.

Fig. 111 represents a group of the Beeston Foundry Co.'s "Decorated" radiators, the three widths in which this is made

being shown. They are $4\frac{1}{2}$ inches, 7 inches and 9 inches wide, the latter being of the three-column design. Plain radiators in two patterns are also made, and the heights are

FIG. 112.

FIG. 113.

24 inches, 30 inches, 36 inches and 39 inches. Ventilating and other radiators of special design appear in this firm's catalogue.

Figs. 112 and 113 are examples of the Meadow Foundry Co.'s radiators, named the "Peer" and "Count" respectively.

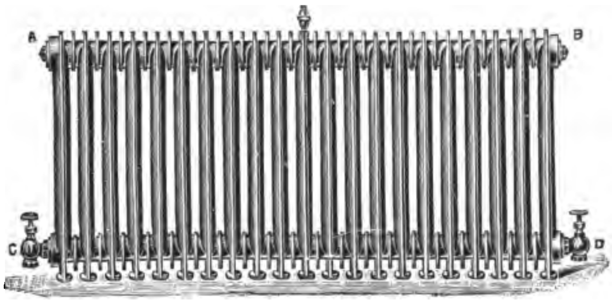
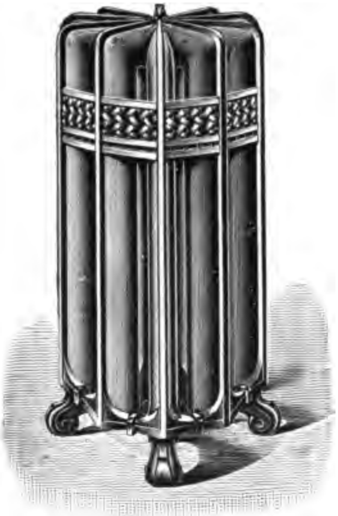


FIG. 114.

The sections or loops are $7\frac{1}{4}$ inches wide and made in 21-inch, 26-inch, 32-inch, 38-inch and 42-inch heights. These can be had with ventilating bases, also of a slightly more ornamental design.

Fig. 114 is Keith's "Universal" radiator, made in all customary heights, and 5⅓ inches wide from front to back. It differs from all others in being cast in one piece, the maker considering the absence of joints an improvement.

Fig. 115 is Keith's "Aiolian" radiator, an elegant and well-considered design. This is built up in sections, but the nipple joints do not come centrally from front to back, but are closer to the back as can be seen. This radiator can be had in various heights and widths, also in a variety of patterns to



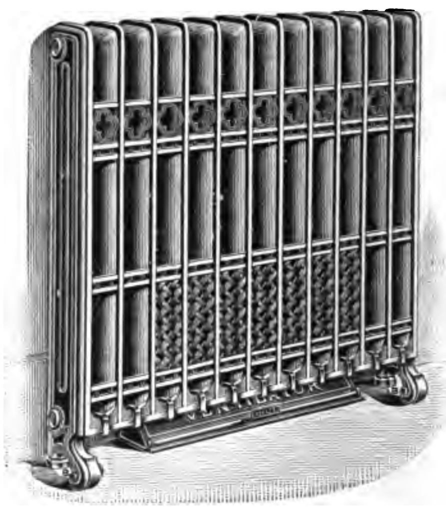


FIG. 115.

meet different requirements. It is also made in several forms as a ventilating radiator.

Fig. 116 is Hayward Brothers & Eckstein's "Safford" radiator, this being 7½ inches wide and made in 20-inch, 26-inch, 32-inch and 38-inch heights. This radiator is made also in less and greater widths and in plain as well as ornamental designs. It is also to be had with ventilating base and in special forms for all requirements.

Fig. 117 is Messenger & Co.'s double-column radiator,

built up in sections the same as the preceding examples, but having an exceptionally large area of surface per section.

FIG. 116.

In 39-inch height each section has nearly 8½ square feet of surface, the section being 11 inches wide. Single-column

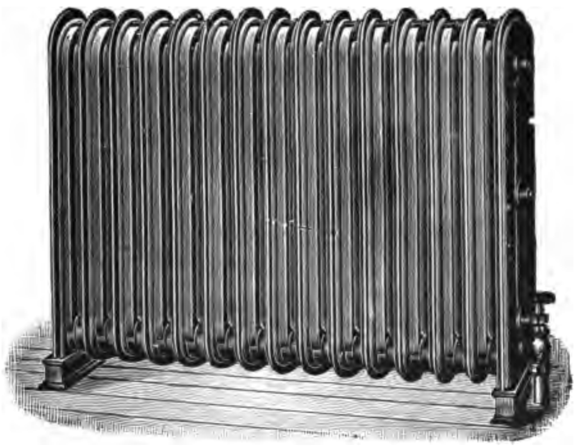


FIG. 117.

radiators of this type are made in two sizes, the sections being 6¼ inches and 4½ inches wide, the heights running 24 inches, 30½ inches and 39 inches. This firm makes what is known as

the "linen-fold" pattern of radiator, a more close and box-like design, yet still consisting of a number of vertical sections joined by nipples.

A departure in what may be termed plain radiators is Haden's "Design 41" illustrated in Fig. 118. This firm makes a speciality of heating works for large institutions, and the radiators they make are designed and built on hygienic

FIG. 118.

lines, yet without wanting a bold and pleasing effect. They have just designed and made a special radiator for hospital use, the tubes being well apart and so arranged that there is the least possible area for dust lodgment, and all parts are quite easily cleaned. At the time of going to press an illustration of this was not available.

Fig. 119 is Longden & Co.'s "Sunbeam" radiator. This

is a narrow make of radiator, only projecting 3½ inches from the wall. The heights are 12 inches, 18 inches, 24 inches, 30

FIG. 119.

inches, 36 inches and 40 inches. Quadrant, half-circular and circular forms can be had, and a wider design is made with ventilating base.

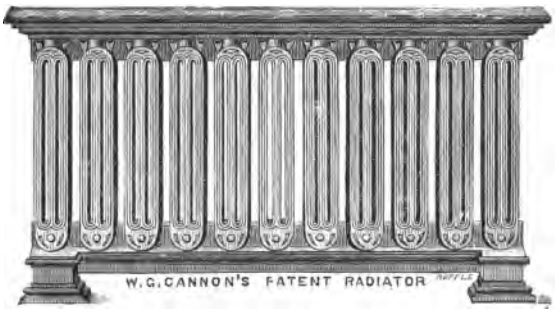


FIG. 120.

Fig. 120 is Cannon's radiator, made in 24-inch, 28-inch, 30½-inch and 35½-inch heights. It has a very small projection, coming about 4½ inches from the wall.

FIG. 121.

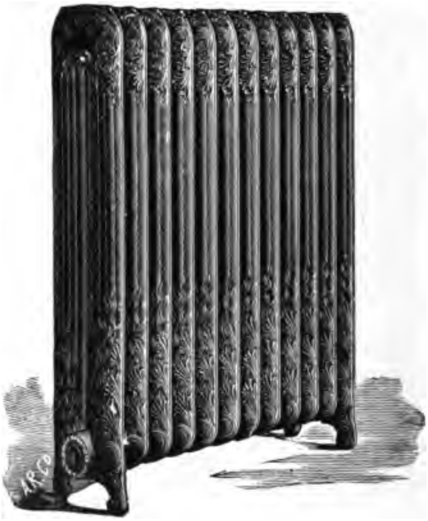


FIG. 122.

FIG. 123.

Radiators of American Manufacture
(stocked in England).

The American Radiator Co. rank first as importers of these goods, being manufacturers on a very large scale and holding immense stocks in England and some continental countries. The space at command can give but a poor idea of the variety of designs made by this one firm, the radiator section of their English catalogue consisting of 64 pages with something different on nearly every page. Figs. 121, 122 and 123 show examples of what are termed one-column, two-column and three-column radiators, while a four-column can be had if required. All can be had either plain or ornamental, and, as will be seen, the ornamental designs are several. Fig. 124 is an elaborate design, moulded by a well-known Italian artist, and having, when enamelled white, the appearance of porcelain.

Another factor holding large stocks of American radiators is H. Munzing, 180 Upper Thames Street, London. Fig. 125 is his "Coronet" radiator, and Fig. 126 the "Imperial." With the latter is given a view of the end section to show the detail of design and its good appearance. Both these can be had plain, and the heights run 19 inches, 25 inches, 31 inches, 37 inches and 45 inches. Fig. 127 shows a wall radiator as supplied by the same firm. This is made in two sizes, and as the tappings are arranged for either horizontal or vertical fixing, they can be connected up to suit any space. The illustration shows two sections connected up horizontally. Special brackets can be had to carry these.

Radiator Valves and Accessories.

One of the most useful radiator fittings we have is the Angle Valve, which is shown in Figs. 128 and 129. Previous to the introduction of this the straight valve had to be used, and made a comparatively unsightly piece of work at that end of the radiator. By means of the angle valve, no pipe or pipe-fittings need be visible above the floor, and the general

FIG. 124.

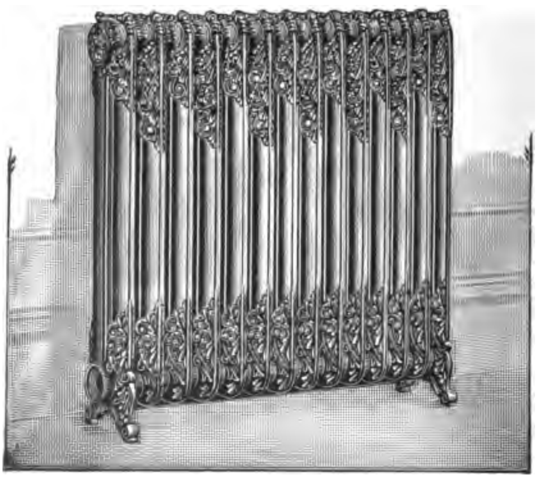


FIG. 125.

appearance, on the floor where the radiator is, leaves nothing to be desired. Fig. 26, page 56, will give an idea of this.

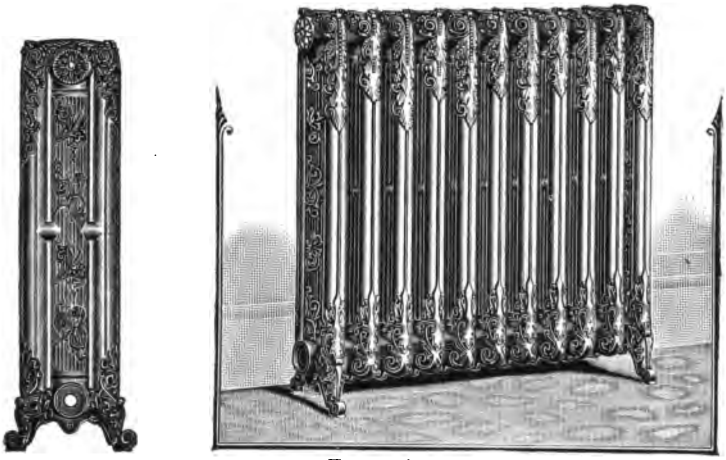


FIG. 126.

The valve has an ebonised wood wheel-head, and the body can be had in polished gun-metal or nickel-plated. The

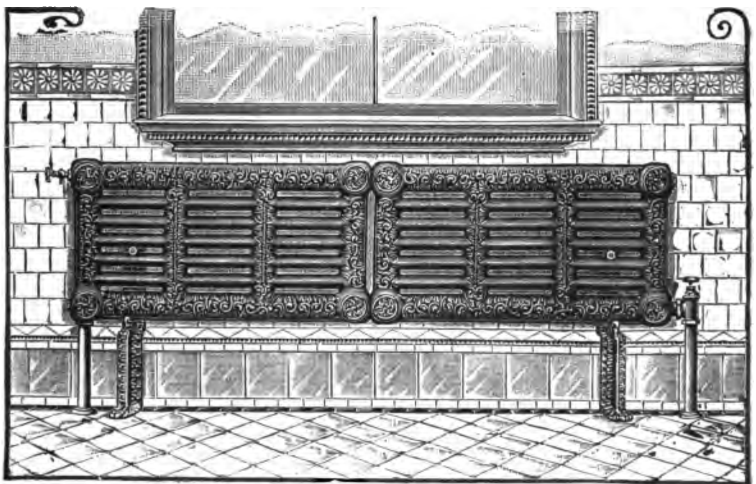


FIG. 127.

second of the two valves illustrated is described as "with union," the union being the radiator connection. The majority of engineers never use this valve without the union

(together with a union-elbow, see p. 212), for, as explained on p. 56, it is quite the common thing to have to remove the radiators for the convenience of decorators or other tradesmen, apart from the possibility of disconnection being required by reason of a leak or for the engineer's own purposes. The small extra expense for the union is a profitable outlay as a rule, and it simplifies the work to some extent. This valve, in its angle form, has a nearly full way through it.*

FIG. 128.

FIG. 129.

Fig. 130 illustrates another angle valve, one which was known as the "Detroit" valve originally, but now appearing in most catalogues. This is a quick opening and closing valve. It is not a screw-down, the centre barrel being turned by the wheel head, much the same as the plug in an old-fashioned plug-cock is turned. This inner barrel is open at

* It will be found mentioned more than once, that for, say, a 1-inch valve to have only a ¾-inch or ⅝-inch way through it is unreasonable. If a 1-inch service is required for any purpose, why choke it with a valve which is quite foreign to a 1-inch measurement except at the tapping—the screwed part? If a valve is described by a certain size, then its way—the passage through it—should be equal to the area of the pipe to which it is attached; otherwise, it is much like paying, say, a 1-inch price for a ¾-inch article, so far as results are concerned.

the bottom, so that the water comes up through it, and then passes to the radiator by way of the opening shown in the side of the barrel. It is an angle plug-cock in fact, but has a full way.

The valve first described, Figs. 128 and 129, is of the screw-down kind, and to open it full, or close it, takes quite twenty hand turns. (The hand turns the wheel-head about one-fourth to one-third of a complete revolution with each movement.) This is often found to be something of an annoyance, and the quick-opening (and closing) valve is considered to overcome it. But this latter valve, which the writer has tried fairly, does not work smoothly, and much as a quick opener is wanted, he has had to fall back on the screw-down valve. What would so well meet the case, and which no one appears to have yet made for this purpose, is a quick-opening screw-down valve. Such valves have been made for draw-off purposes and answered well. They open or close with one complete turn, or in some cases a half turn, and in one instance the writer had such a valve that needed a quarter turn only. A fault that appeared in this valve, when cheaply made, was that the abrupt thread would not hold the seating water-tight, when it had worn a little; and the valve, which then leaked, was not easy of repair. But this fault could have no existence in radiator work, as the valve is so seldom used that it could not wear loose in the thread, and if it did, then the pressure is not all on one side of the seating, as it is with a draw-off cock; again, if it leaked a trifle, it would only leak from the pipe into the radiator; lastly, the valve need not be made with such an abrupt thread, for if it opened and closed with, say, one and a half or two complete turns, it would suffice. There is certainly room for something between the present screw-down angle valve and the quick-opener just illustrated.

FIG. 130.

A near relation to the angle valve is the Corner Valve

illustrated at Fig. 131. This is of service when a pipe is brought through the wall against which the radiator stands, and in a line with the radiator connection. An ordinary angle valve could be used, but it would require to be fixed on its side, or horizontally, as it is called, with the stem of the wheel-head in a line with the floor, instead of being upright. The corner valve fills the purpose with an upright stem, and the wheel-head in its proper place, but it must be explained that in most cases it is without the full-way and clear air-way, which the angle valve has. If reference is made to Fig. 133, it will be seen that the corner valve is in reality a

FIG. 131.

FIG. 132.

globe valve, but with one opening at right angles to the other, and it can possess all the faults that the globe valve has. What, therefore, has to be ordered when corner valves are required, is that they have a full-way, and that their internal construction does not admit of air being locked in. The writer knows that a full-way corner valve is made, but has not yet seen one quite free from the air-lockage fault.

The screw-down Globe Valve has an external appearance as Fig. 132, while its water way is indicated by Fig. 133. A fault the writer referred to in the footnote to p. 208 is always present in this valve, and it is commonly found that the water-ways are contracted to about one-half the area of the pipe the

valve is attached to. Added to this the way is very crooked, and the total result in this respect is as bad as it can be. This by itself would be sufficient to condemn the valve for most purposes, but there is another fault, this being the certainty of air being locked in on one side or the other, if the valve is fixed in a pipe which runs horizontally. This latter difficulty can be overcome by fixing the valve on its side, but although this may prevent air being locked in, it does not straighten the water-way nor increase its area.

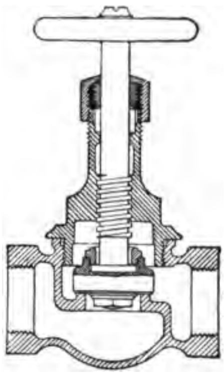


FIG. 133.

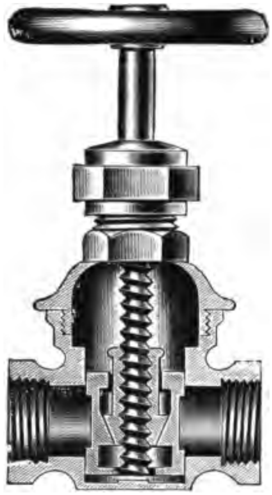


FIG. 134.

The Peet's pattern or Gate Valve should always be used in straight runs of hot-water pipes, whether mains or branches, horizontal or vertical. The interior of such a valve is illustrated in Fig. 134. Not all valves of this type are constructed exactly as shown, but the working principle remains the same, this being to raise or lower one or a pair of discs, the gate as it is termed, which, when raised, leaves a straight clear way through the valve of a size quite equal to the bore of the pipe the valve is attached to.

A fitting which, as a radiator connection, is about as useful as the angle valve is the Union-Elbow, illustrated at Fig. 135.

The purpose of this is to admit of the end of the radiator which comes opposite to the valve, being connected up without visible pipes, and having as good an appearance as the valve end. Fig. 26, page 56, shows this, and as the elbow is made of gun-metal, and can be had polished or nickel-

FIG. 135.

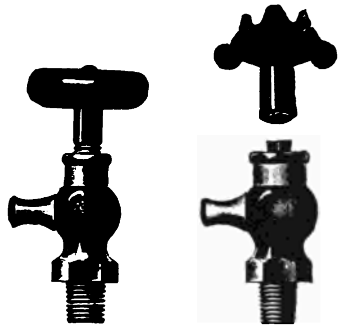


FIG. 136.

plated, the general effect is very good. When speaking of the advantage of having a union to the valve to allow of easy disconnection, it will be understood that a union at the other end of the radiator is equally necessary, and this elbow provides it.

Every radiator requires an Air-Cock, and Fig. 136 shows two of these. These are not the only designs made, but they represent those most generally in use. The one with a wheel-head matches the angle valve, as the head is of black wood; the body is nickel-plated. The other valve has a similar body, but the key is loose, which makes it better suited for shops, public places, schools, children's nurseries, etc.

FIG. 137.

Automatic air-valves, for hot-water work, have not been in demand to any great extent in the past, a probable reason being their high price, compared to that of an air-cock. There has also been a feeling of doubt as to their reliability. Fig. 137 illustrates the "Monash" (Robt. W. Blackwall & Co.,

Ltd., 59 City Road, London), and this carries a five years' guarantee with it. It will be seen that any attention required can be given to the valve without emptying the radiator or stopping its regular work. Another valve of the kind is illustrated in Fig. 137*a*, this being made by the James Keith and Blackman Co., Ltd. This also is made so that attention can be given to the interior of the fitting without emptying the radiator.

FIG. 137*a*.

A fitting which must be put on every boiler, or in a flow pipe near the boiler, is. a Safety-Valve. A table of sizes best suited for apparatus of various extent is given on page 50, and it is only necessary to describe the valves here.

The least expensive safety valve for general use—and there need be no hesitation in using it—is the weighted lever valve as Fig. 138. This might be likened to the angle radiator valve, described on page 208, only that the seating is held down by a weighted lever, instead of being screwed down. The screwed outlet to this safety-valve is to admit of a pipe being used to carry away any water that might issue, if the valve came into operation. This pipe need not be fitted, however, nor is it recommended, as these valves very rarely come into operation, and when they do, it should be plainly seen and

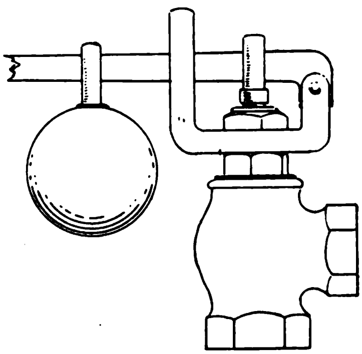


FIG. 138.

promptly attended to. It is different when the valve is put upon a steam boiler, as it may be blowing-off quite frequently, and the issuing steam can make the boiler house unbearable, if it happens to be a small one; a pipe is then used to discharge the steam outside.

Figs. 139 and 140 illustrate the dead-weight type of safety-valve. This valve is adjusted to bear different pressures, or heads of water, by removing, or adding to, the ring

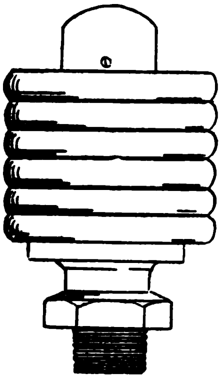


FIG. 139.

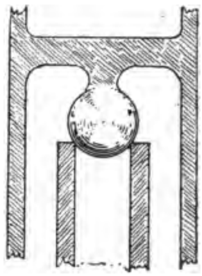


FIG. 140.

weights shown. The interior construction of the valve differs in some makes, but the one illustrated is considered the most reliable and sensitive. It has what is termed a knife-edge seating, this being obtained by a spherical upper piece resting in the end of a tube, as shown. It follows that a ball, very accurately turned, resting in an annular opening, also accurately turned, will make a water-tight joint, yet where the two surfaces meet, the contact is little more than a knife edge. It is a very sensitive valve, as will be understood, and if by long disuse the parts "grow" together (get stuck together) it requires but a very little force to separate them. A trifling fault, if it can be called such, that this valve possesses, is that its seating can be so readily injured. The finest particle of grit, or a scratch, will usually lead to leakage, but the likelihood of this happening can be lessened, if not obviated, by putting the valve in a less conspicuous place than usual, where it will not get knocked or played with.

Fig. 141 illustrates a hot-water thermometer, specially designed for use in a heating apparatus. This screws into the outlet of a tee, and the projecting hollow stem at the bottom comes into the full current of the water in the pipe the tee forms part of. As illustrated, the thermometer is suited for a tee with the outlet looking upwards, and this would be in a horizontal pipe. For vertical pipes the bottom stem of the thermometer is at right angles, so as to screw into a tee with horizontal outlet. The ingenious detail of this thermometer lies in the bottom stem. This is easily removed, and is found to be a short length of very thin tube, closed at the bottom, and quite half-full of mercury, and is spoken of as the mercury bath. The stem comes away at the joint just where the arrow points (being usually held by a small set-screw), so that it can be inserted into the tee, and made sound before the thermometer itself is fixed. When the stem is away the thermometer is found to have a bulb of mercury at the bottom of its tube, the same as ordinary thermometers, only that the bulb is a little more than an inch below the bottom. This makes the bulb dip deeply into the mercury bath when the thermometer is in position, and thus a mercurial contact, and a correct transference of heat, is obtained between the water and the bulb.

FIG. 141.

The object of the hollow stem is to admit of the thermometer being repaired, a new glass tube put in if necessary, without emptying the apparatus of water, and it also prevents leakage in case the thermometer is broken. The bulb of the thermometer might go direct down into the water, without using the hollow stem and its bath of mercury, but as a thermometer tube is a fragile thing, the hollow stem has been devised to admit of breakage occurring without leakage or even inconvenience. It will be understood that it would not do to let the bulb come down into the stem without the latter containing mer-

cury. If the stem was empty, that is, containing air only, the thermometer could not register the temperature of the water correctly. The loose mercury in the stem makes a perfect metallic contact between the water and the bulb, and the results obtained are the same as if the bulb rested naked in the water.

The writer seldom erects a hot-water heating apparatus without one of these appliances, and sometimes uses two or more on the same installation. It can be made to nearly approach an automatic regulating device, for in any case it automatically indicates the temperature of the water, and the attendant can by this means keep a proper degree of warmth in a building without going inside it, or having anything to directly indicate what the temperature is there. The plan adopted is, after having the apparatus in regular use a few days, to write out on a card what the heat of the water is to be, according to the outdoor temperature. Three of the lines from the card hanging in the writer's boiler-house read thus :

When the outdoor temperature is :		Keep the boiler thermometer at :
32°	.. ..	175°
38°	.. ..	150°
45°	.. ..	130°

The attendant, a youth, has a thermometer hanging conveniently outside the boiler-house, and there is a thermometer in the chief flow main facing him, as he stokes the fire, and although he never enters the warmed part of the house, it is exceptional that he has to be told to increase or decrease the heat. He tends the fire and keeps the indoor thermometers within about one degree of the warmth wanted without seeing them or being told. In one instance, where two hot-water thermometers were used, one was at the boiler, while one was on a main flow pipe that passed near the manager's room (in large club), and this enabled the manager to see if the stoker was attending to his boilers carefully, and keeping the water temperature according to the card. Failing some such arrangement as this, it is to be wondered at how a proper warmth is obtained and kept. The stoker cannot be

running into the rooms to ascertain how they feel, nor can he have messages sent to him continually. If he is skilled he can doubtless guess it cleverly, but taking heating works for all purposes, how many are tended by clever stokers?

Fig. 142 illustrates an appliance that serves a useful purpose, and helps to make the boiler look business-like. It is an Altitude Gauge, its purpose being to indicate head of water, though it will indicate any increase or decrease of pressure in the boiler, whatever the cause. The figures represent the head of water in feet, and the hand or indicator extending across the dial is the one that moves with any alteration in pressure. The shorter spear-pointed hand is colured red, and is stationary, except when moved by the fingers. Supposing an apparatus, when filled and in use, indicates a head of water of 25 feet. The ringed pointer would point there, and the red hand would be moved by the fingers until it came beneath the other, and only showed a disc of red through the circular hole in it. This would be the normal state of the gauge; and only upon an abnormal pressure, high or low, being felt would the red hand be exposed, and it would then be considered as a danger signal indicating something wrong. It will be understood that this gauge immediately registers a loss of head of water, a thing that is not so quickly discovered in the ordinary way.

FIG. 142.

As yet we have no English made appliance or devi-e for automatically controlling the damper of a hot-water boiler, but it may be of interest to describe an American fitting devised for this purpose. Fig. 143 shows this in section, and it is known as Power's hot-water regulator and Thermostat. It may be explained that the Thermostat is confined to the part marked, while the remainder is the regulating device. To explain the regulator first, let it be supposed that the thermostat is absent, as the regulator is both made and used to act

separately and by itself when required. It will be seen that the largest piece of the complete appliance is an upright cylindrical casting with a water-way shell having a top and bottom pipe connection. This part is inserted in a flow pipe, or a branch flow circulation arranged for it. The water that passes through the shell is to be representative of that in the whole apparatus, as its heat will control the fire and the temperature everywhere. In the middle of this shell is a space

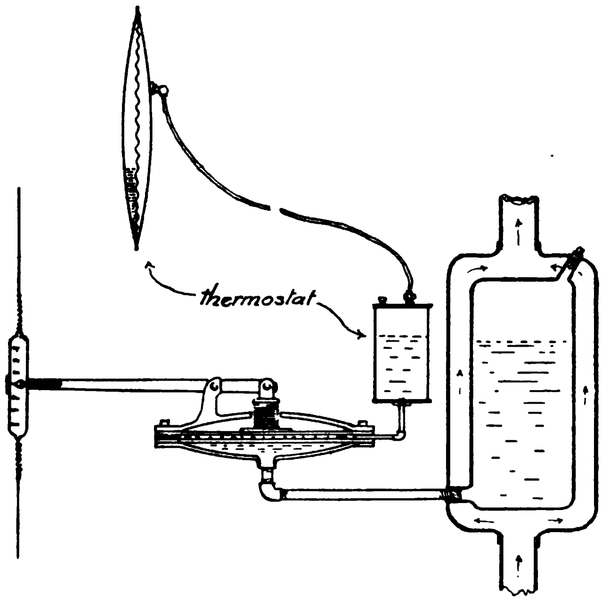


FIG. 143.

containing water or alcohol, this being filled in by the small plug shown. This inner chamber has direct communication with the underside of a sheet rubber diaphragm, shown in the part which extends from the chamber. When the heated water circulates through the shell, it immediately heats the liquid in the inner chamber and causes it to expand. The expansion of the confined liquid causes a pressure to be exerted beneath the diaphragm, tending to lift it, and thus operates the lever above, which has direct communication with

the boiler dampers.* The dampers, it is needless to say, require to be balanced to allow of this operation occurring with precision.

It will be seen from the foregoing that the "regulator" portion of Fig. 143 provides for the automatic control of the dampers by the heat of the water in the flow pipe, but it makes no provision for automatically varying the heat of the water according to the external temperature—the weather. This can be done by hand, by manipulating a pointer at the end of the lever (not shown in detail) which will cause the dampers to be opened more or less, according to the position of the pointer. This, however, is not automatic, and to have the heat of the water regulated by the warmth of the house the Thermostat portion is added. The upper part of this is circular—a disc, but shown in section in this illustration (Fig. 143). The outer convex plates are stiff, but extending right across, in the centre, is a corrugated flexible division as shown (in section). On one side of this division is a small quantity of liquid that boils, and gives off a vapour (equivalent to steam), when it reaches a temperature of about 60° F.; so that when the air of a room becomes of a comfortable warmth, this liquid begins to steam. The effect of the steam is to force the flexible division over towards the other side, and this exerts a pressure on the air contained there. This air space communicates by a metal tube with the small vessel shown, this vessel containing water or alcohol, and having communication with the diaphragm. It will be noticed that the diaphragm is double, that is, consisting of two sheets of rubber with a space between. This is only necessary when the thermostat is used, as the regulator needs but one. The effect of the air pressure described is to cause a pressure to be exerted on the surface of the liquid in the small upright vessel, and this pressure is transmitted to the space between the rubber diaphragms, causing the upper one to rise and operate the lever.

* American boilers are usually provided with two dampers, one the "draught-damper" in front of the ash pit; the other, the "check-damper," in the flue nozzle. A cord or light chain extending from one to the other, passing over pulleys in the ceiling, allows of both being worked together.

By this means the temperature of a room is brought to control the dampers, but it requires to be noted that only one room can be put to this purpose, and the warmth of that room will control the heat everywhere. On this account the thermostat requires judgment and care to be exercised when it is installed.

Fig. 144 shows a group of four Expansion Joints. When long and perfectly straight runs of pipe occur, it is usually necessary to make some provision for the expansion and contraction (lengthening and shortening), that occurs in the pipes when the water is heated or cooled. In horticultural work, where pressure is scarcely felt, provision is made by either a

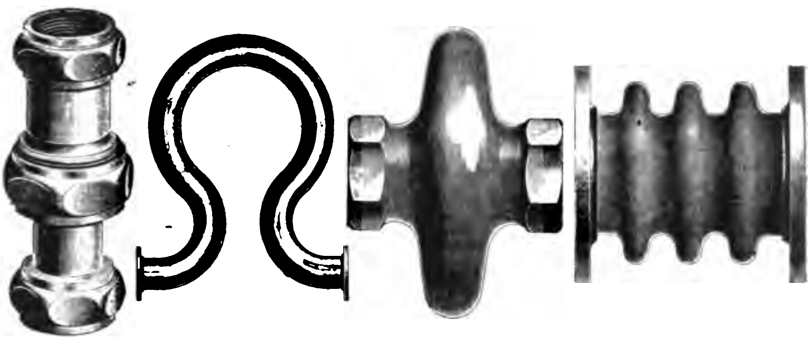


FIG. 144.

loose long-socket, packed so as to act as a stuffing-box, or by using plain rubber ring joints as explained later, but these are not possible in buildings where the pressure is always too great for such simple expedients. When cast pipe is used for mains, it is a common practice to use a rubber-jointed pipe, particulars of which are given later, and each joint, although drawn up tight, makes sufficient provision for expansion in itself. These are always known as expansion joints, but they have no relation to the joints just illustrated.

When flanged cast pipe, or wrought pipe, or any tube having rigid joints, is used for long runs, then every effort should be made to break the direct line of the run, so as to make a natural provision for expansion ; for however well a

specially made expansion-joint is constructed, it is always better to do without it. In running mains along a long corridor, or culvert, for instance, it may be possible to let them cross from one side to the other every forty to fifty feet, for, as stated, it is only necessary to break the direct run to make a natural provision for expansion and contraction. Some judgment is needed in this, however, for a break of only two feet would not be sufficient for any size of pipe; in fact, it is scarcely sufficient for a 1½-inch pipe, as there is no spring in such a short break, unless the pipe is small. It might be roughly calculated, for wrought pipe, that the least break should be, for 1½-inch pipe, 36 inches; 2-inch pipe, 48 inches; 2½-inch pipe, 66 inches; 3-inch pipe, 84 inches, and so on. In case the term "break" is not quite clear, Fig. 145 is given to show what is meant.

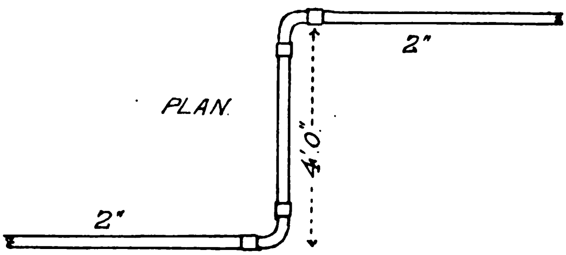


FIG. 145.

The expansion joints, shown in Fig. 144, are named as follows: from left to right, "stuffing-box," "loop" or "horse-shoe," "bellows" and "concertina." The first of these is made up of one tube sliding within another, both accurately turned, but relying chiefly on a stuffing-box to keep the joint water tight. It is not liked so well as a joint without a stuffing-box, but it takes the least room of any. The loop or horse-shoe joint is liked best by most engineers, while the bellows pattern comes next in approval. Any of them can be had with screwed or flanged ends. Copper is the metal used for all except the stuffing-box joint, and this is made either wholly of gun-metal, or with an iron casing and gun-metal working parts.

WROUGHT TUBE AND TUBE FITTINGS.

On the next page are given some illustrations and the universal English price list of wrought-iron tube and fittings, this price list being given for convenience of reference in making up estimates. The list stands for tubes of all qualities, viz., gas tube, plain or galvanised, water tube, plain or galvanised, and steam tube, plain or galvanised. The difference in cost is arranged by a difference in the trade discount allowed in each case.

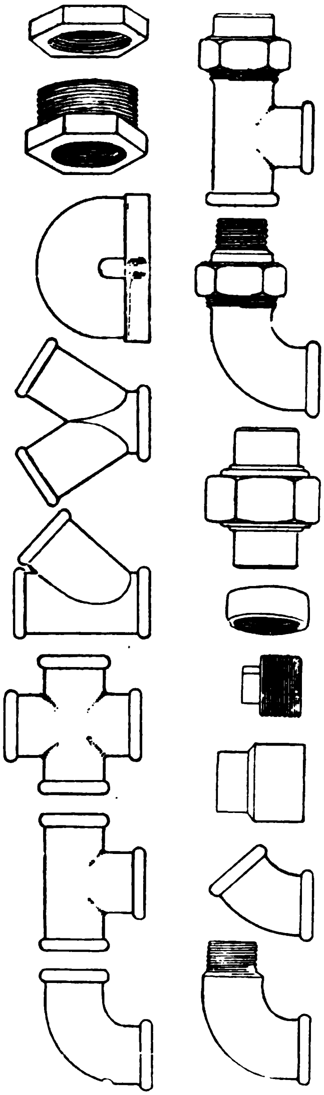
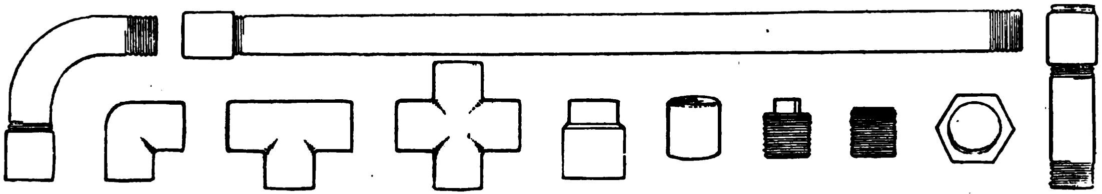


FIG. 146.

Fig. 146 represents a group of American malleable cast-iron pipe fittings, for use with wrought tube. These are of more elegant form and finish than the wrought fittings, while in certain details they excel also. The elbows are so cleanly and evenly rounded that bends (as we know them) are unnecessary. The threads, too, are tapped slightly taper so that as the pipe is screwed up it makes a good metal-to-metal joint. Again, the threads in these fittings stand up clear of the metal which is beyond the threads, so that instead of the end of a fully tapped pipe coming abruptly against solid metal at the end of the thread in the fitting, it can go on until a full thread-to-thread joint is obtained. These



PRICE LIST OF WROUGHT-IRON TUBES AND FITTINGS.

This is the universal list of English Manufacturers, and is subject to a trade discount.

Internal Diameter in Inches.	½		¾		1		1¼		1½		2		2½		3	
	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
Tubes, 2 to 14 ft. long, per foot	0	4½	0	6	0	8½	1	0	1	3	1	9	3	0	3	6
Pieces, 12 to 23½ in. long, each	0	11	1	3	1	9	2	6	3	3	4	7	8	6	10	6
Ditto, 3 to 11½ " " "	0	7	0	10	1	1	1	6	2	0	2	10	5	6	7	0
Long Screws, 12 to 23½ in. long "	1	0	1	4	1	10	2	8	3	6	5	0	9	7	12	0
Ditto 3 to 11½ " " "	0	8	0	10	1	2	1	8	2	3	3	3	6	4	8	3
Bends . . . . . "	0	10	1	0	1	6	2	6	3	0	5	0	12	0	18	0
Tees . . . . . "	0	11	1	2	1	5	2	0	2	6	4	3	9	6	16	6
Elbows, Square . . "	0	10	1	0	1	4	1	10	2	5	3	10	9	0	14	0
Ditto, Round . . . "	1	0	1	3	1	6	2	1	2	7	4	6	10	0	17	0
Crosses . . . . . "	1	11	2	4	3	0	4	0	4	10	7	9	21	4	40	0
Nipples . . . . . "	0	3	0	3½	0	4	0	6	0	8	1	0	2	3	3	6
Barrel Nipples . . . "	0	7½	0	9	0	10	1	3	1	8	2	6	5	8	8	9
Backnuts . . . . "	0	3	0	3½	0	5	0	6	0	8	1	1	2	3	3	6
Caps . . . . . "	0	5	0	6	0	8	1	0	1	3	2	0	4	4	6	0
Plugs . . . . . "	0	4	0	5	0	6	0	8	0	10	1	3	2	6	4	9
Sockets, Plain . . . "	0	3	0	3½	0	4½	0	6½	0	8½	1	1	2	6	3	6
Ditto, Diminished . . "	0	5	0	6	0	7	0	9	0	11	1	4	3	3	5	0
Flanges . . . . . "	1	0	1	2	1	4	1	9	2	0	2	9	5	0	8	6
Springs, not socketed . "	0	7	0	9	1	1½	1	11½	2	3½	3	11	9	6	14	6

For relative areas of pipes, see Table in Appendix.

fittings are now stocked by several English factors, and they have a large sale, but at the time of writing, there is still complaint that faulty castings are met with more often than is liked, and needless to say, this is a considerable cause of annoyance, owing to the fault being undiscoverable until the apparatus is complete, charged with water and tested. There is no doubt, however, that the malleable cast fitting has come to stay, for it is cheap and offers distinct advantages.

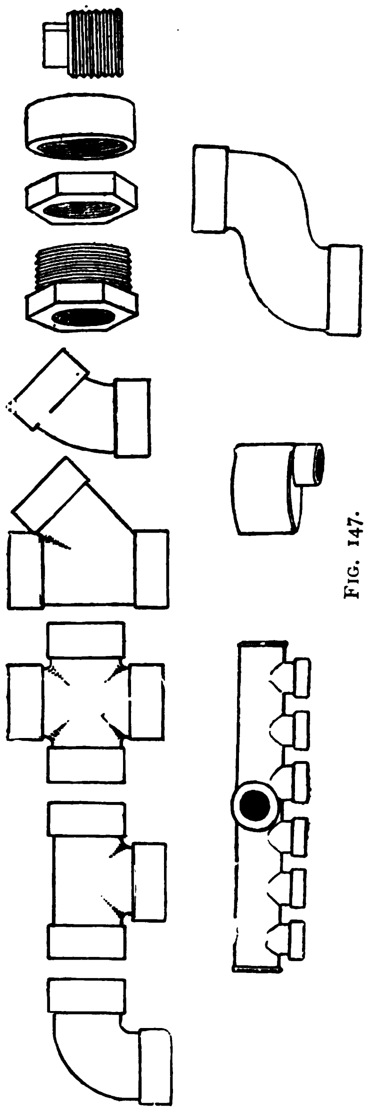


FIG. 147.

Fig. 147 is a group of American soft-cast fittings, which are now stocked by English factors. They are intended more for large wrought pipe, 2 inches upwards, and while their appearance is heavy, they possess all the good detail of design and construction that the malleable fittings have. The illustrations given are by no means complete as to the variety of fittings made.

There are certain ingenious special fittings that figure in the lists of American goods, which can be referred to here. One is the reducing fittings, which are made with eccentric outlets. Both reducing sockets and bushings can be had made in this way, also tees, though the latter are not always stocked.

An eccentric reducing socket is shown in the group of soft cast fittings, Fig. 147, it being a reducing socket with the small opening out of centre and near the edge. To show its use let Fig. 148 illustrate a horizontal pipe reduced in its straight run with an ordinary reducing socket, while

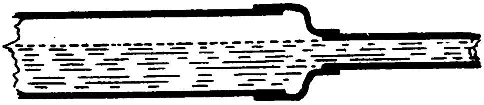


FIG. 148.

Fig. 149 shows the same pipe with an eccentric reducing socket. In the former air is locked along the top of the pipe; while in the latter the upper line of the pipes is level and unbroken.

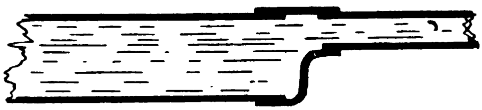


FIG. 149.

Another special fitting is the tongued or diverting tee, shown in section by Fig. 150. This is intended to divert a portion of the flowing water from a main into a branch service, one that otherwise might be passed or neglected. Considerable care has to be exercised in the use of these fittings, or they may divert the water too successfully, and it is only in rare cases that a more normal way of getting the required result cannot be obtained. The writer invariably favours new ideas and inventions, but the advantages of this tee are so small that up to the present he has never found occasion to use one. If a service is run wrongly, and does not have a circulation, this tee will not put it right; while if the service is run correctly, the tee is not required.

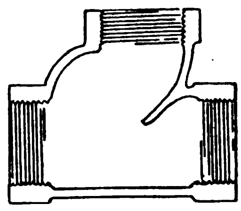


FIG. 150.

CAST-IRON HOT-WATER PIPE AND FITTINGS.

On the five following pages appear practically all the ordinary fittings that are made and stocked for cast-iron socketed hot-water pipes. These illustrations are given to enable the student or engineer to see the fittings ordinarily made, also what he can get ready made to meet special or urgent requirements. A peculiar source of trouble is sometimes experienced with these goods by reason of the varying thickness of the metal. It is usually noticeable as between pipes and fittings, and it has been stated that the difference is due to the moulders being paid by the piece for one and by weight for the other. In any case it is desirable, when settling on a maker who is to be bought from regularly, to see that this trouble does not exist, or is not too pronounced.

Cast-iron hot-water pipe is made in 9-foot, 6-foot and 3-foot stock lengths (except the 2-inch size, which is not made in greater length than 6 feet). It usually has a socket at one end and a small rim at the other—termed the "spigot" end; but it can be had with two spigot ends, for making up coils, etc. The pipe can also be had with a trough cast upon each ength, this trough being provided to receive water and make the air humid in horticultural work (see p. 99), or loose troughs can be had to rest upon the ordinary plain pipes. The pipe is heavier than either rain-water or cast smoke-pipe, and the sockets are strengthened with cast rings. The sockets, too, are fully large to allow of a caulked joint being properly made.

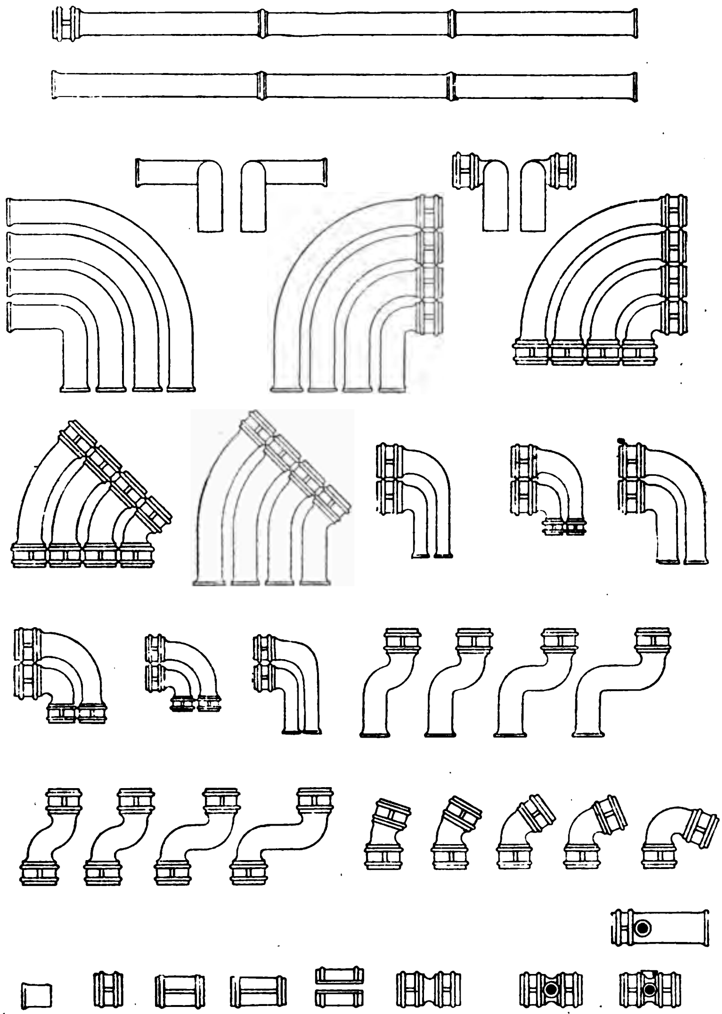
JOINTING CAST-IRON HOT-WATER PIPES.

There are several ways of jointing the ordinary cast hot-water pipe, the cheapest lasting joint being made with iron borings and known as the rust joint.

Rust joint: Take 80 to 100 parts, by weight, of iron borings,* 2 parts of powdered (flour) sulphur, and 1 part of

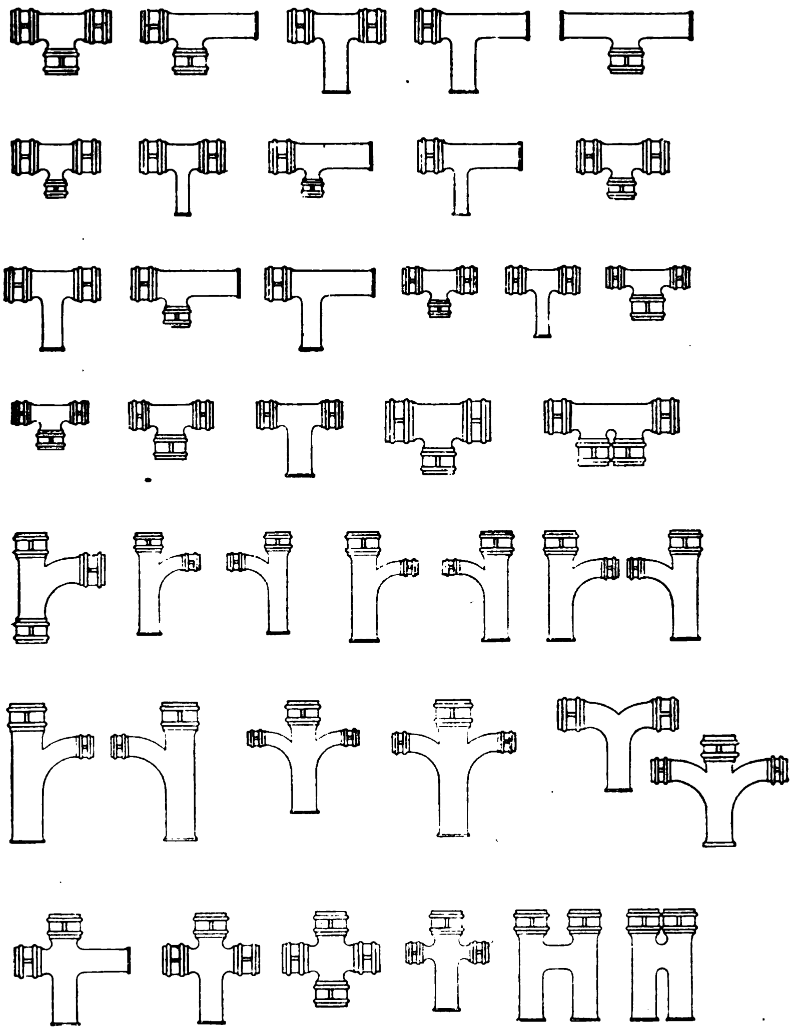
* Iron borings are supplied cheaply (3*s.* 6*d.* to 4*s.* per cwt.) by those firms who deal in cast hot-water pipes. Borings should be well pounded if they appear to be too coarse.

powdered sal-ammoniac; thus, to 1 hundredweight of borings there would require to be about $2\frac{1}{4}$ lbs. of sulphur and, say, 18 oz. of sal-ammoniac. These must be well mixed in a dry



state, then have water added and mixed until the mass is of a uniform moistness. This should be done from one to two hours before the material is required for use.

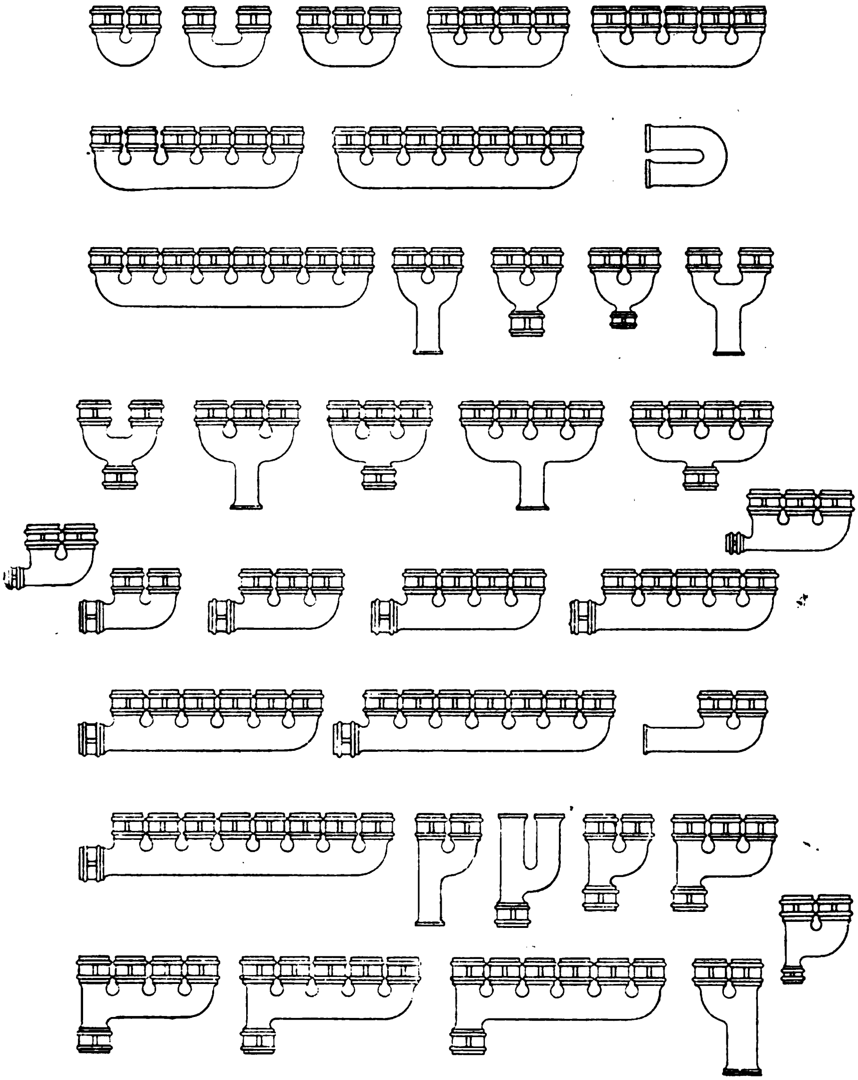
In making the joint it must be understood that the yarn, or gaskin, first caulked in, is the actual joint-making material,



and the boring mixture, when it has set hard, only serves to back this up and keep it sound.* On this account the water

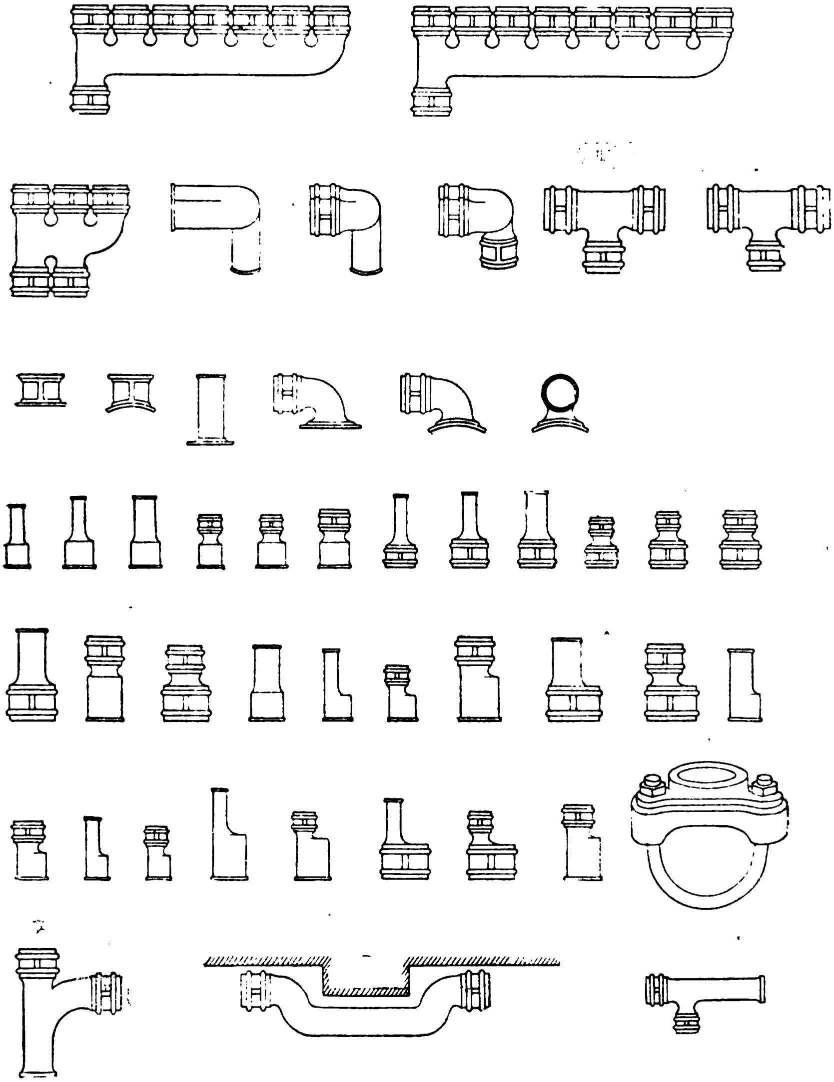
* In a case of emergency some old tarred rope was once used to make caulked joints with, and this, without any backing, lasted well and had to be burnt out when the pipes were removed.

should not be turned into the pipes until the borings have set, and although very little thought is given to this in glasshouse

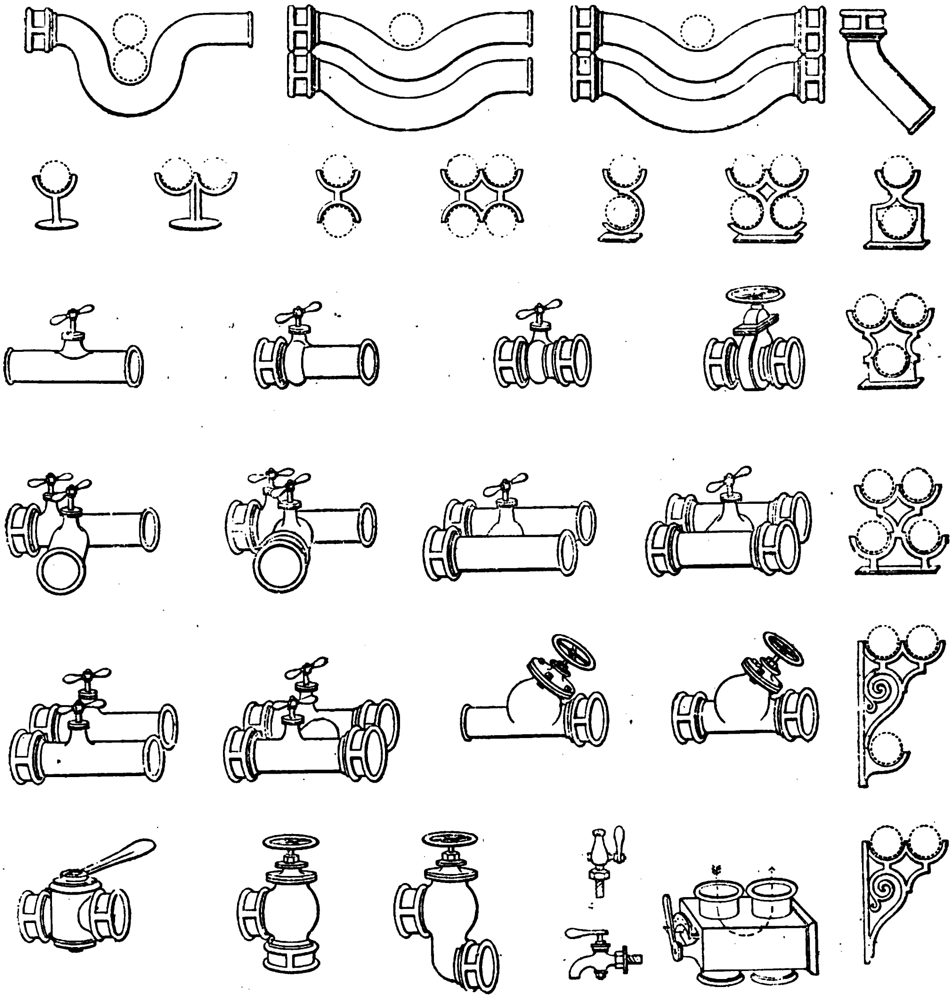


work, in which the pressure is so light, yet even in this case the joints should be allowed from one to three days for

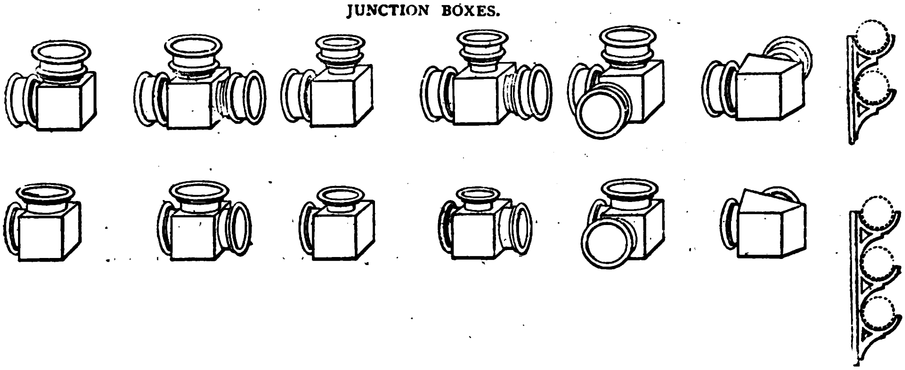
setting. The minimum might be considered as one day for 2-inch pipe, one and a half to two days for 3-inch pipe, and



two to three days for 4-inch pipe. This is for horticultural work, or wherever the pressure is practically *nil*, and, as stated, these should be the least times allowed for the borings to set.



JUNCTION BOXES.



In making the joint a length of yarn, making about three turns round the pipe, is first caulked soundly in, and this is followed by other lengths until the socket is a little more than half-full. As regards the precise quantity, various fitters have different ideas, and while some consider the joint should be half yarn and half borings, others caulk in yarn until only half-an-inch space is left for the borings. Doubtless, this is sufficient if so small a quantity can be got to set well, and on the latter account about three-quarters of an inch of borings, and from this to one-inch may be found best for the larger pipes (3-inch, 4-inch, or larger).

The chief reason for limiting the quantity of borings is its liability to crack the socket owing to its expanding a little as it sets. If it were not for this, the borings might be used liberally, as it is a cheap material, and would reduce the quantity of yarn required. It must be plainly stated that a man's capability in joint-making with this material is quickly known by whether he gets cracked sockets or not, and many tons of pipe have been rendered useless through this. The best advice that can be given is to use only a reasonably small quantity of borings, and to caulk or press them in evenly, but not too hard. They should not be used too fresh, yet no more must be mixed (that is, moistened) than can be used the same day, as they will not keep long without setting.

When a few joints only are required, and borings are not readily obtainable, red and white lead putty may be used. With this a length of yarn is first caulked in, then a layer of the putty, then yarn and putty alternately until the socket is full. To make a good job of this some of the putty should first be thinned with boiled oil, and the socket and spigot painted with this on the surfaces where the packing material is about to come. This joint is not a cheap one, nor does it set quickly.

A good substitute for the red and white lead joint is a mixture of two parts dry slaked lime or whitening (or powdered chalk will do), one part of litharge and two parts sand, these being mixed with boiled linseed oil to make a putty. This is caulked in alternate layers with yarn as last described.

A joint that is largely used when the conditions will admit is made with a plain rubber ring.* A ring of round cord rubber, of bare ½-inch thickness, is stretched over the spigot end of the pipe, and this is then thrust into the socket. If the socket is an even casting, and the ring of proper thickness, a sound joint is obtained without doing anything else. Where rubber ring joints are used no other provision for expansion is needed, but it will be seen that full provision must be made for supporting the pipes, as the joint has no rigidity whatever. Sometimes the ring is backed up with cement to keep it firm. A rubber ring makes a good provision for expansion if used here and there on long runs of rigidly jointed pipes.

A form of joint that is now being used largely with every success consists of a rubber ring, which is compressed when

FIG. 151.

the joint is tightened up. The tightening is done by bolts and nuts, and the ends of the pipe, or one end, at least, are cast to a special design for this purpose. An early pattern of this joint is Jones's patent, illustrated by the two drawings of Fig. 151. The statement just made that the pipes have to be provided with specially designed ends must be withdrawn in this case, as the pipes and fittings have all quite plain ends, not even a socket being used. This is the joint sent out with the complete apparatus which is sold for amateurs' own erection, as illustrated at Fig. 43, page 94, for anyone with but a slight knowledge of tools can make up this joint. It consists of three iron collars and two rings of square rubber. The two outer collars, as will be seen, when drawn together,

* The rubber ring joint is largely used by professional growers, as the men employed on the grounds can readily put up new runs of pipe, or alter old ones, with this joint. The rings are stocked by all firms supplying the pipe.

compress the rubber rings on to the inner metal collar, and this makes a perfectly sound joint. It is not intended that this joint be used for works in which a high pressure is felt, consequently it is not suited for the basement mains of a heating apparatus in a high building.

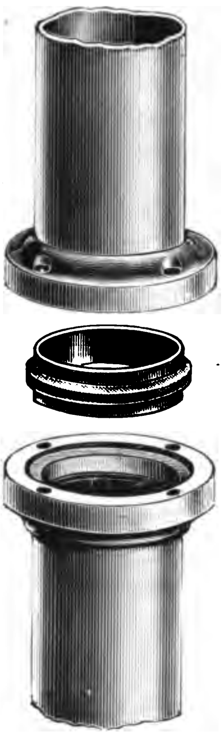


FIG. 152.

The same makers* have a joint designed for bearing high pressures, this being illustrated by Fig. 152. This necessitates the use of specially designed ends to the pipes and fittings, these ends, when drawn together, compressing a rubber ring on an interior iron collar as shown.

The two illustrations of Fig. 153 show Richardson's Patent Universal joint, as made by the Meadow Foundry Co. This is a reliable joint for high pressures, and it will be seen that, as one end of each bolt is a hook, bearing on a shoulder, a pipe or fitting can be twisted round and fixed at any precise angle required.

The illustrations of Fig. 154 show Messenger's joint. This will bear pressure and possesses the advantage of only requiring one end of the pipe to be of special design, while the other end is plain. By this means a pipe can be cut on the job, whereas with joints requiring two specially designed ends to the pipes and fittings there usually have to be some odd lengths cast to order to finish a job with. It may be explained, however, that the makers of joints requiring two special ends always keep a fitting or joint that can be used on a cut pipe, and so save the time that must be allowed for casting an odd dead length ; or, as special lengths are a common demand, the makers hold themselves in readiness to cast these at short notice, and when a high pressure has to be withstood, it is better to wait a day or two for this than use a plain-ended

* Jones & Attwood, of Stourbridge.

cut pipe. When heavy pressures have to be borne, say 70 feet and upwards, the writer prefers that both ends of pipes and fittings be specially moulded.

A fitting that is associated with cast pipes, and which will bear description, is the "saddle" shown on the sheet of illus-

FIG. 153.

trations, page 230, on the extreme right side the second line from the bottom. This is to enable a wrought pipe branch connection to be made, when the cast pipes cannot be drilled or taken down for the insertion of a tee. A hole is cut in the

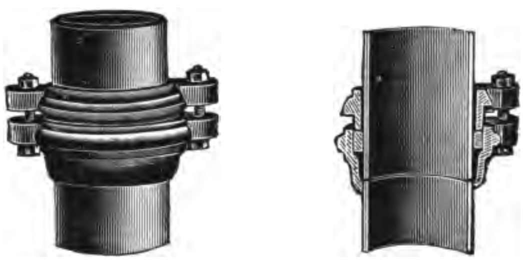


FIG. 154.

pipe with a diamond-point chisel, and when it is of suitable size the saddle is bedded on with red lead putty and hemp, and then drawn down tight on to the pipe by the nuts shown. The hole in the pipe need only be of a fair shape, and does

not need to be carefully finished or tapped with a thread. The tapping for the wrought pipe is in the hole shown in the saddle.

Finally it may be stated that when a number of small branch connections have to be made on cast mains, the majority of makers are prepared to cast bosses or stubs on some of the lengths of pipe, as Fig. 155, these bosses being drilled and tapped for wrought pipe. This comes much cheaper than inserting a pair of tees for each small branch, for

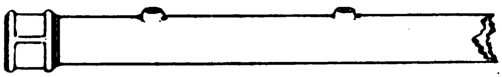


FIG. 155.

the tees must be provided and fitted with blank ends to the outlets, these ends being drilled and tapped for wrought pipe. Where, say, a 3-inch one-pipe main is run round a basement to carry about a dozen radiators, the insertion of two-dozen tees is a real trouble and expense compared to having the bosses just described.

Tees, when used for this purpose, should have the blank ends to the outlets drilled eccentric; that is, the hole for the wrought pipe should come out of the centre and close to the upper edge of the blank end, see page 225.

CHAPTER XV.

THE HIGH-PRESSURE SYSTEM.

THE high-pressure system of heating by hot water has its principle based on the fact that if, when water is heated, ebullition or boiling is prevented, the temperature that the water can attain is very high, and considerably above the generally recognised boiling point of water, which is 212° Fahrenheit. This latter temperature is that at which water boils when heated in open vessels (or vessels with loose lids), at sea level, at which level the pressure or weight of the atmosphere is 14·7 lb., or nearly 15 lb., to the square inch. If we ascend a mountain (where the pressure is less), or descend a deep mine, below sea-level (where the atmospheric pressure must be greater), the boiling point of water will be found to be less or greater than 212° F. On the summits of many high mountains water boils at a temperature which is insufficient to cook most foods.

When water reaches its boiling point and ebullition occurs, it ceases to rise in temperature, as the heat which would go to continue the rise passes away with the steam. This being so, it will be seen that if the pressure on the water can be increased, by some means, then a proportionately higher temperature can be had before boiling occurs, and by a simple arrangement it is possible to prevent boiling entirely.

It might be thought from the foregoing that if pressure and temperature worked together when heating water, the temperature would have no reasonable limit. This, however, is not correct, but it is possible and easy to have a hot-water heating apparatus in which the temperature of the water

ranges from 300° to 400° F. At these temperatures the pipes will do much more work than surfaces heated by low-pressure hot water or steam, and yet not be dangerous. The writer has heard that a temperature of 600° F. has been attained, but this may have been an assumed temperature, for it could not be obtained without an exceedingly powerful boiler coil—probably an accidental circumstance—and then it is doubtful whether the trouble was taken to test the heat with a suitable heat-measuring instrument. There is no obvious reason, however, why 600° F. should not be got in a sealed apparatus, with an excessively disproportionate boiler coil, and then the conditions would be dangerous in most cases. In properly erected works, the average temperature is 300° F., which, with good stoking, may rise a little higher.

If the water is not to boil, then the apparatus must be sealed, and all ordinary atmospheric influences excluded. This could be done with any hot-water apparatus by sealing off the expansion pipe and the cold supply; but it would result in the destruction of the apparatus, as the tubes and appliances ordinarily used will not stand the pressure. Even with the tube specially made for the purpose, there has to be provision for the expansion of the water, as will be seen presently.

In Fig. 156 is illustrated a high-pressure apparatus in a simple form which will afford a means of describing the details that have to appear in works of this kind.

The apparatus has to consist wholly of tube. No boiler or radiator is possible, on account of the pressure. A coil is used as the heater in the furnace, and coils or rows of pipe distribute the heat. The tube is all of similar size and strength, the apparatus being in fact an endless line of tubing except for the short and larger piece of tube shown at top, and two other small connections. To withstand the maximum strain that may occur, the tube is made of unusual strength, being of $\frac{1}{4}$-inch metal, lap-welded. The bore is $\frac{13}{16}$-in. (usually called $\frac{7}{8}$-in.), while the external diameter is $1\frac{5}{16}$-in. Instead of the tube having the usual right hand thread at each end, one end has a right, the other a left hand thread, and the socket is threaded right and left accordingly. It follows, therefore,

that when the ends of the tube are put into the socket and the socket screwed up, the ends are drawn together until they meet in the centre of the socket.

The pipe joint is a very important detail in high-pressure work, and the only reliable method is that of making a metal-to-metal joint, as shown in Fig. 157. In this it will be seen that the end of one pipe is finished flat, while the other is coned all round. When the socket is screwed up and the

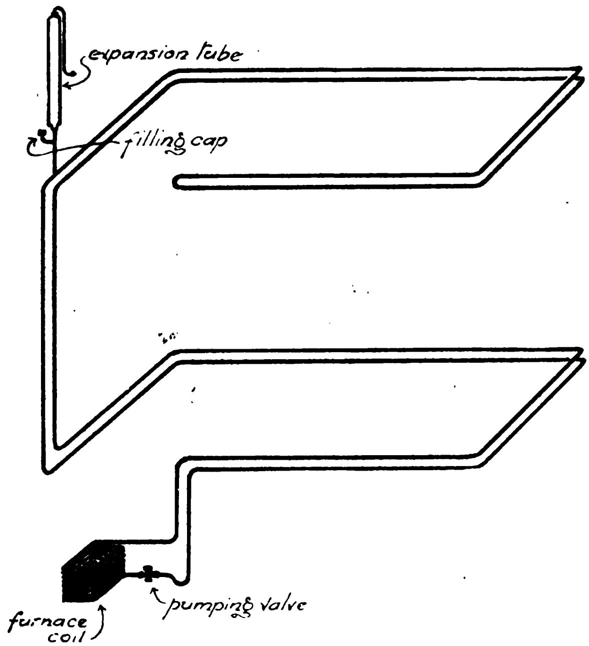


FIG. 156.

ends of the pipe come together, it follows that the coned edge embeds itself in the flat end, and this, if properly done, makes a sound pressure-resisting joint, without any jointing material, such as red lead or hemp. No packing or jointing material is used in this work.

The tools used for preparing the ends of the tubes are usually shop-made, and, correctly speaking, there should be one for the coned end and one for the flat-faced end of each

tube. Quite commonly the fitter considers a file sufficient for the flat-end, also for the outside bevel of the coned end, while he provides a tool resembling a countersink for the inner coned surface. The flat end is then filed true, and the outer surface of the coned end is filed also; the inner surface is made with the tool just mentioned, worked by a brace. It is very important that both ends shall be at true right angles to the length of the pipe (or the ends would not meet true when drawn together), and this is generally tested by means of a small steel square.

The threads on the pipe ends, both right and left, are finer than the ordinary iron pipe thread, viz., fifteen threads

FIG. 157.

to the inch, this being necessary to effect the best joint when screwing up. Special stocks and dies, also special tongs or grips, are sold for this work, the latter being, as will be understood, very requisite. The stocks only require two dies, one of each hand, as the size of the pipe seldom varies now. A $\frac{5}{8}$-in. pipe was largely used at first, but the $\frac{7}{8}$-in. size seems now to be generally preferred. The smaller size, and the tools required, may often be needed by anyone undertaking repairs. The necessity for securing a very sound joint will be apparent when it is stated that every apparatus erected has to be tested (cold hydraulic pressure) to 1800 lb. or 2000 lb. to the square inch, before lighting the fire.

The fire coil or heater is composed of the same tube as the circulation, and the quantity of tube used for this always bears a fairly exact relation to the length outside the furnace. This will be referred to again, but it may be here stated that in a general way the tube in the fire coil is equal to one-tenth of that outside the furnace.

In constructing the furnace coil, whether it be large or small, the pipe is usually bent round to an oblong shape, one pipe above the other, as Fig. 156 shows; and although this is by no means an ideal economical means of utilising the fuel, yet it is the form of heater most commonly used. The coil is either set in brickwork or placed in an iron case, the latter making it independent of brick-setting. The rule is to put large coils in brickwork and make the small ones independent.

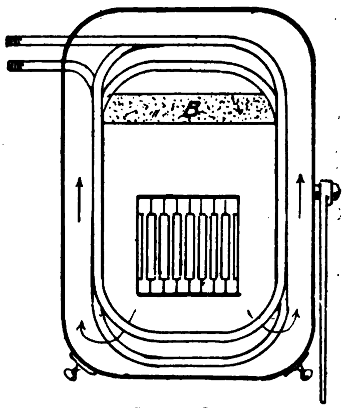


FIG. 158.

Fig. 158 shows, in plan, a coil in an iron case. The coil has its tubes, at the front and rear, projecting and receding alternately, as may be seen with the front of the four-pipe coil on page 246, this hit-and-miss arrangement being provided that the flame and heated gases may pass to the flues outside the coil and from thence to the chimney. The arrows (Fig. 158) show the passage of the flames and gases. The barrier marked B is a brick bridge extending across inside the coil, and so preventing the flame and gases making a short cut to the rear of the coil where the chimney is. This bridge extends up to the top and quite cuts off communication from the front to the rear of the coil, except by the flue-ways outside the coil. The flame and gases after coming through the side flues pass up between the tubes at the rear and then into the chimney, and by this means the interior and exterior of the coil are heated as well as is possible.

At the bottom of the furnace is a grating which is hinged at the rear, and, by means of a lever handle outside, this grating can either be rocked to clear the fire of ash, or it can be dropped to let the cinders and ash fall out when the furnace has to be cleared out entirely. This provision is necessary, as no stoking door can be provided in front, the coil proving a barrier to any access to the fire at this point. If the iron casing extends to the ground, then an ashpit door (with means to regulate the draught) is put in front below the level of the fire bars; and there have to be provided two flue doors for cleaning the side flues outside the coil. The top of the furnace is usually composed of firebrick slabs resting on the top of the coil, and above these the iron top to the case comes. In this top is a feeding hole and cover, all fuel being passed in this way. Fig. 159 shows an independent heater, as made by Wontner Smith, Gray & Co., and although the description just given may not, perhaps, apply to this heater in every particular, it will be found to have a general application.

A variation to the ordinary form of coil boiler is that patented and made by Renton Gibbs & Co., of Liverpool. Fig. 160 illustrates this, and it will be seen to consist of a number of lengths of larger tubes running from front to rear of the furnace, and arranged in the form of an arch from side to side over the fire. The ends of the large tubes are reduced and connected together by the smaller size of tubing used in this work; and when the extent of the installation requires it, the arch of tubes is divided into groups for whatever number of separate circulations may be decided on. This arrangement is fully explained with the four-pipe coil shown on page 246.

A detail that may next be explained is the piece of large pipe shown at the highest point of the apparatus, Fig. 156. This is known as the expansion tube, and it fulfils a very important purpose. It must first be explained that water is a non-elastic, incompressible substance, yet it expands with some freedom when heated. Therefore, if an apparatus as Fig. 156 was erected, minus the expansion tube, and, after being filled with water, was sealed up, it could not long remain

unfractured after lighting the fire. It could not fail to burst notwithstanding the great strength of its tubes. The purpose of the expansion tube, therefore, is to prevent fracture, which purpose it fulfils quite perfectly, as will be seen.

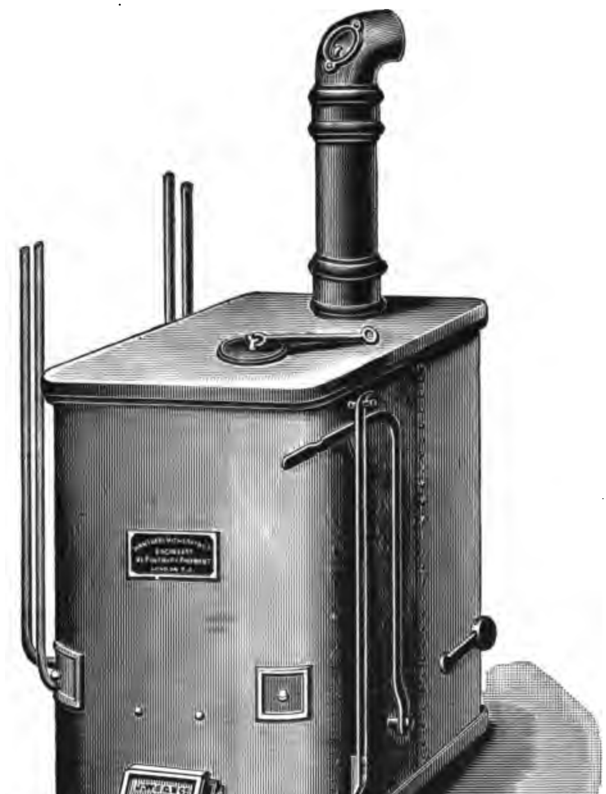


FIG. 159.

By referring to Fig. 156 it will be seen that a tee is inserted just below the expansion tube, and the outlet of this tee is closed with a cap and marked "filling-cap." This cap

is the highest point to which the apparatus is filled with water (when cold), the tube above this containing air only. When the apparatus is charged and sealed, and the fire lighted, the water commences to expand, and the force it exerts compresses the air in the expansion tube, the water partly filling it. Air is highly elastic, and permits the water to expand into its greater bulk with no more force than that which is necessary to compress the air, this strain being insufficient to rupture the apparatus at any point, if the parts are properly proportioned.

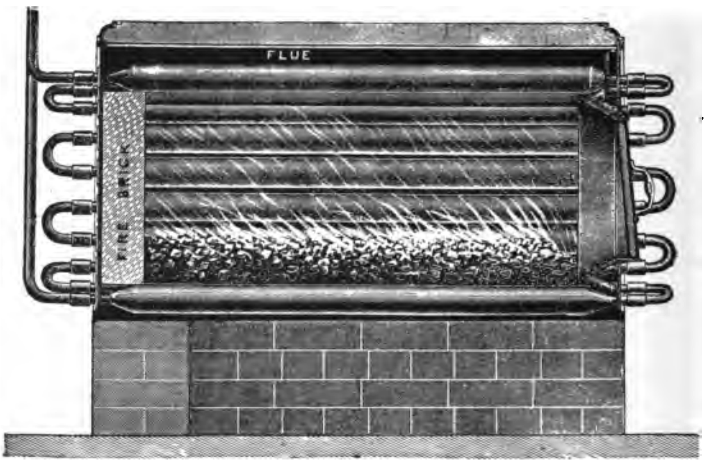


FIG. 160.

The air in the expansion tube is therefore an elastic cushion, against which the expanding water can exert its force; but another office fulfilled by the expansion tube is that of preventing ebullition or boiling. It was explained that, by increasing the pressure on water, the temperature at which it boils or ceases to become hotter is increased proportionately. It will be seen that, as the water heats and expands, it causes a pressure to be exerted on itself by the fact that the air is compressed inside the expansion tube. The compressed air exerts a pressure back upon the water equal to the pressure

the water has exerted in compressing it. In other words the expansion of the water compresses the air, but the air is, all the time, pressing back on the water. As the water becomes still hotter, seeking to reach its boiling point, it expands still more and increases the pressure in the expansion tube. Therefore the hotter the water becomes, the greater the pressure it makes on itself in the expansion tube, and thus it is doubtful whether boiling could ever occur. The expansion tube, therefore, serves the double purpose of preventing rupture, and permitting of high temperatures being readily attained by the pressure its contained air exerts on the water.*

The apparatus, illustrated by Fig. 156, would only be suited for small purposes in which the run of radiating pipe would not exceed about 500 feet. It is never desirable to attach a great length of tube to one heating coil for the simple reason that, with so small a pipe, the cooling is so rapid that the greater part of the return pipe would be comparatively cold. By referring to any of the tables in this book giving the sizes of main pipes for low-pressure work, it will be found that a pipe of a certain size can only carry a certain amount of radiation, and the reason is that a given size of pipe can only allow of a certain amount of heated water coming through it to replace that which is cooled. In low-pressure work a pipe of $\frac{7}{8}$ inch diameter (if such were made) would only be given about 45 square feet of radiation or, say, at the utmost, 200 lineal feet of pipe of its own size. With high-pressure work the circulatory movement is stronger and the temperature is higher and, therefore, a boiler coil can be given as much as 500 lineal feet of $\frac{7}{8}$-inch pipe, but this should be the outside limit, and any less quantity will be more beneficial than otherwise in results.

Assuming the foregoing argument to be correct, and there can be no doubt about this; it may be asked how it happens

* This may be a suitable moment to state that when it appears desirable, two or more expansion tubes may be used on one apparatus, in which case they would be smaller ones, as the aggregate capacity need only be that required by the table on p. 259. In an apparatus the writer saw, which consisted of three large coils or stacks of pipe, there was an expansion tube and filling cap to the top of each, and the periodical attention to the filling cap kept the coils full of water.

that many works exist in which thousands of feet of radiating pipe are doing good work, yet one furnace heats the whole. This is easily explained by saying that the furnace contains what appears to be one large coil, but which is, in reality, several distinct coils intercoiled and heated by one fire ; and, strange as it may appear to the uninformed, these several coils, and the different sets of radiating pipes outside the furnace, are all one continuous endless tube.

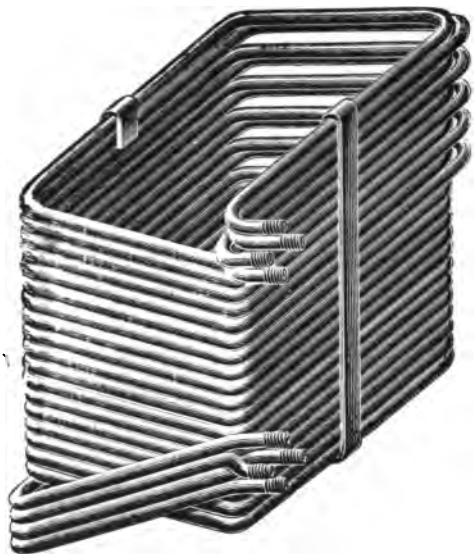


FIG. 161.

It is always claimed for the high-pressure apparatus that it is quicker in doing its work than the low-pressure, and moderately short circulations are essential to secure this speed, otherwise the high-pressure system might take as long as the low in giving a certain degree of warmth. When, therefore, an apparatus exceeds 500 feet, some plan has to be adopted for dividing the piping scheme into two or more circulations, each starting out from and returning home to the boiler coil separately and without branching. This has

also to be done without breaking the continuity of the pipe—that is, still leaving it one endless run of tube. This to the inexperienced may appear to be a difficult task, yet in practice it is very simple.

Supposing the apparatus consisted of 1600 feet or 1800 feet of pipe, and this was divided into four (or more) circuits as it should be, the furnace coil would then be made up of four distinct pipes, as indicated by Fig. 161, presenting four flow ends and four return ends to be connected on to, as shown. In connecting up it is important not to let the pipe

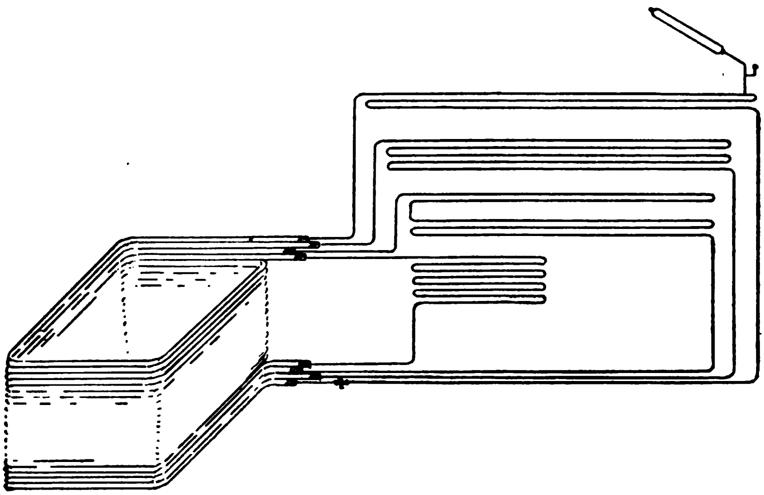


FIG. 162.

going out from one flow come home to the corresponding return, as this would give each circulation a distinct furnace coil, and each one would require a distinct expansion tube and other details. Furthermore, unless each circuit and coil had the same length of pipe and the same work to deal with, there would be trouble owing to the fire affording more heat to one than another, causing great irregularity in general working.

The plan of connection that has to be adopted is to let the circuit going out from the flow of one coil come home to the return of another. Fig. 162 will show how this is done,

but to make it quite clear Fig. 163 is given, this illustrating the four coils separated. It will be noticed first that the whole apparatus remains one endless pipe, which is a very

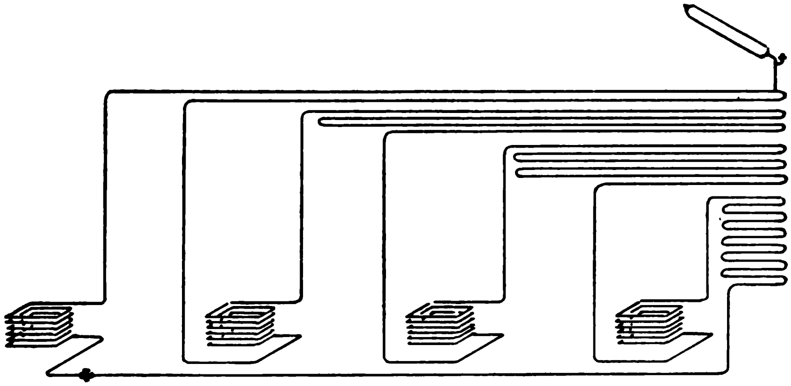


FIG. 163.

necessary detail, as will be explained directly; secondly, that as the water goes round one circuit and becomes cooled, it is soon back at the furnace to be re-heated. Thirdly, although the apparatus consists of four circuits and coils, only one expansion tube and filling device is needed to the whole.

FIG. 164.

In making the apparatus consist of one endless tube one chief result aimed at is to admit of proper filling. The filling is invariably done with a pump connected at the bottom of the apparatus, generally in the lowest return pipe near the furnace coil. Some engineers use the "pumping-through cock," as Fig. 164, while others prefer the "pumping valve," which is usually of their own private design. In

either case the device admits of pumping water into and through the pipe in one direction, and continuing the process until the tubing is full and water arrives back at the pump from the other direction. Only by this means is there any assurance that all air is swept out of the circulations. Occasional instances occur in which branches are necessary, and then trouble—little or much—may be experienced in the filling. Only well-skilled men should attempt branching an apparatus of this kind, and it will be found that the more experienced the man is the more anxious he will be to avoid branches.

In Figs. 165 and 166 are given the working principle of a pumping valve made by W. Stainton, of King's Cross Road, London. This may be considered as a specially formed four-

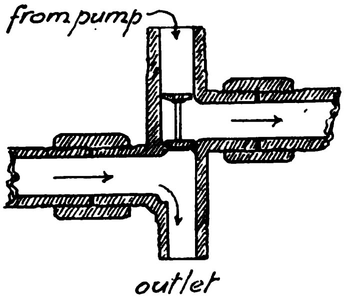


FIG. 165.

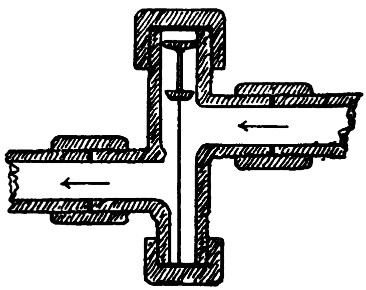


FIG. 166.

way or cross-piece, and the illustrations show the valve; the first one while pumping, i.e. filling is proceeding; the second one, when closed and the water circulating.

Figs. 167, 168 and 169 illustrate a pumping valve made by Renton Gibbs and Co., of Liverpool. The two first show the valve with hose connected at bottom from the filling pump, while the third shows the valve closed and the direction in which the water circulates.

The writer does not believe that the pumping valve is considered to be superior to the pumping-through cock in doing its work, but it is neater and is a preventive of trouble due to people meddling with the fittings. There may also be something in the fact that the pumping-through cock admits of a local man being called in to do the periodical re-pumping,

whereas, with the valve, this is not quite so likely. Engineers undertaking this work, usually, on completion of an apparatus, ask if they may book an order to attend to the installation regularly, and send their man to re-pump it before lighting the fire each autumn, and at the same time do any repairs to the furnace, etc., that may be necessary. It is a regular job someone has to do, and it is highly desirable that only an experienced man should do it. The pumping valve is rather an assistance in this, as it is a device an inexperienced man would not understand, and would hesitate to meddle with.

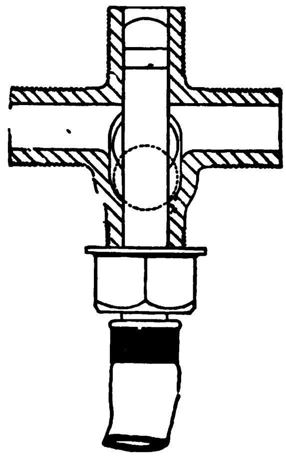


FIG. 167.

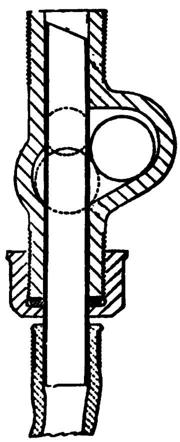


FIG. 168.

It will be noticed that there is a tee just under the expansion tube, this tee being capped off and described as the "filling cap." It might reasonably be supposed that this was the point at which the apparatus was filled with water, but it is not so. It should be called the "replenishing cap," for although it plays no part in the actual filling of the apparatus, the cap has to be removed about once a month and a little water put in, if there is need of any. This is the highest point to which the water reaches, when the apparatus is cold, and a moment has to be chosen when the apparatus is cool, to remove the cap and do any replenishment needed. This

is not done by the heating engineer, unless he should have his business premises quite close to the job. As a rule the engineer leaves a strong wrench with the caretaker, or whoever will be the attendant to the fire, with instructions how to remove the cap and replace it, this being done about once a month (during the time the apparatus is in use) as stated. It is needless to say that this filling cap is always a few feet above the highest point in the circulation, as it is important that any little shortage of water shall not exist in the circulating pipe.* It may seem peculiar that a shortage of water can possibly occur in an apparatus that is first pumped full and then sealed, yet a small shortage does occur, and this is why the regular replenishment is required during the winter, and the thorough re-pumping once a year before the fire is lighted for the winter season.

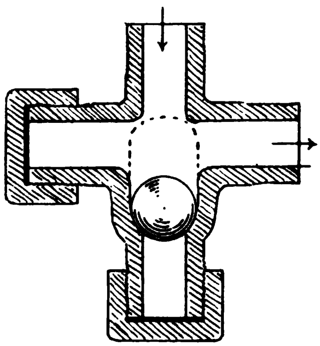


FIG. 169.

The foregoing particulars describe what is usually known as the high-pressure or Perkins' system, and it has been considered that in the hands of workmen who do not correctly proportion the heating coil and the expansion tube to the radiating pipe, or in the hands of an attendant who allows the fire to become too fierce, alarming pressures may be obtained in the apparatus, accompanied by the possibility of dangerous results. It has been stated that a temperature of 600° F. has been known, and this would be accompanied by an exceedingly high pressure, far too high for safety, but there can be little doubt that this statement will bear modifying considerably, and, given the most ordinary care, the apparatus just described cannot be found fault with.

* There is usually an air hole or tube on the upper extremity of the expansion tube, this outlet also being securely plugged or capped. When this exists it should be opened when the filling cap is removed, and closed again when the filling cap is replaced.

The temperature of 600° F. is probably no more than a rumour, for, supposing it occurred (and the apparatus did not "burst," see p. 260), who could be on the spot with proper appliances to test it? There is no record of such a test being made experimentally, and it would be reasonable to say that the rumour has no foundation. If it is desired to avoid any annoyance or trouble that might arise from an attendant over-firing the heating coil, then a pressure gauge can be put in one of the flow pipes, where it will come plainly in view, and the attendant can be instructed never to let the gauge register more than 70 lb., which will mean a temperature of 316° F. When everything is hot he might allow the pressure to drop to 50 lb. (298° F.), or lower.

The reason for mentioning this is that a certain feeling of alarm raised at one time led to an ingenious form of valve being introduced to limit the pressure, this valve taking the place of the expansion tube and filling cap, and although the apparatus remains the same in all other particulars, a new name is given when the valve is used. There does not appear to be any decided name, nor a good name, but the apparatus is then said to be on the "moderate pressure system," or "limited pressure," or "high-pressure system with valve," or "valve cistern," or is given some title conveying the fact that the pressure is under control so far as having an upper limit. This modified form of high pressure apparatus is now in regular use, but it has not superseded the system which has an expansion tube, and the engineer practising this work will find that there is a regular demand for both.

Let it be assumed that a simple form of apparatus is erected, as Fig. 156, but the branch which carries the filling cap and expansion tube carries a valve fixed in a cistern, as Fig. 170, instead. The valve, the principle of which is shown in section in Fig. 171, both discharges and takes in water at times, and this is the reason that it is fitted in a cistern. On examining the valve it will be seen that the major part of it, all the upper part, is no more nor less than a weighted-lever safety valve. Any pressure greater than the inner spindle can withstand must lift the valve end of this spindle from its

seat and discharge whatever is beneath it. At the lower part of the valve will be seen a small unweighted spindle valve. This has its seating and seat so arranged that the spindle lifts with quite a light pressure from the outside, but closes if a pressure is exerted from the inside. It is a sort of check valve in this detail, but the whole complete valve is a device that can act as an outlet valve or an inlet valve, according as the pressure on it is greater inside or outside.

Supposing, therefore, that the outlet part of the valve is weighted at top to allow of its opening, when the pressure inside is about 70 lb. to the square inch. This will mean a temperature of 316° F., which should be the highest limit in

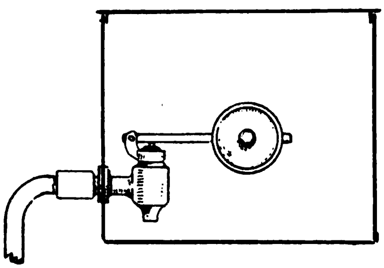


FIG. 170.

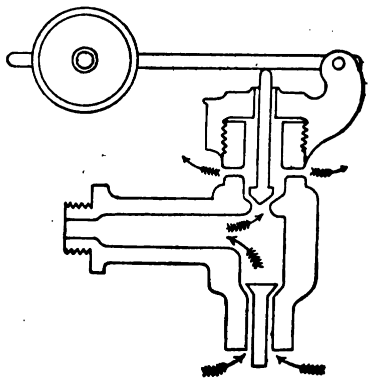


FIG. 171.

this work when put to ordinary uses (see p. 252). Should the fire be urged, or carelessly tended, so that a pressure beyond this figure might be reached, then, at the correct moment, the valve opens and discharges a little water. This instantly checks the rise of pressure (and temperature), and however the fire might be urged the only result would be the possible discharge of a little more water. It will be seen that this safety valve—for that is what it really is—totally prevents any pressure being attained beyond that at which it is weighted or set to open at, and this quite obviates all the supposed risks a sealed apparatus is given credit for possessing.

The inlet part of the valve is provided to admit of water being carried back into the apparatus, when the pressure falls. It is necessary that the apparatus be always full of water and the inlet valve sees to this whenever anything like a vacuum is being formed in the pipes. From this it will be seen how necessary it is that the valve be fitted inside a cistern, and it is equally necessary that the lower part of the valve, at least, be always under water. It would not do for air to be sucked into the apparatus, when the inlet valve opened. It will also be seen that no filling cap is needed for periodical replenishment, and the expansion tube finds a perfect substitute in the weighted valve. The only fault urged against the valve is that, like all valves, it can get out of order. The valve is in almost constant operation when the fire is alight, as every change in temperature means either a discharge or a taking in of water.

Even when an apparatus has this valve, it remains desirable to put a pressure gauge on a flow pipe in the stoke hole, where the attendant can readily see it. Although the valve may be set to open at the pressure accompanying 316° F., it is not always desirable to work up to this temperature in the ordinary way.

It will be understood that the existence of the valve makes no difference to the use of the regular pump-filling device, which is shown in the return pipe near the furnace coil in Figs. 156 and 163. The valve only displaces the expansion tube and the filling cap, the remainder of the apparatus being alike in general principle and detail.

In running the pipes in this work (whether the apparatus has an expansion tube or a valve cistern), it is customary and proper to observe the rule followed with low-pressure pipes, in giving them a rise from the furnace coil, and avoiding dips and irregularities of this kind. But where dips require to be made they can be put with less risk of failure than with low-pressure work, as the circulation is stronger, and, most importantly, they do not become air-locked. The absence of air makes air-cocks unnecessary, and on this account coils of pipe, as Figs. 172 and 173, are quite admissible. Long

runs of pipe up and down the side walls of a hall or place of worship, as Fig. 174, are also quite regular, and no provision for air exit is needed. Pipes can also be carried over doorways or window-heads, but the rule remains that irregularities should be avoided where possible, and not introduced as being the regular thing. There is a too common feeling that the pipes can be run anyhow and anywhere in this work, but it is an incorrect idea, for the motive power which causes the heated water to move through the pipes is brought about by

FIG. 172.

FIG. 173.

precisely the same natural action as it is in low-pressure pipes, but the higher temperature gives it a little more strength and ability to overcome obstacles. The total absence of air, too, is of assistance, as the pumping quite scours it out, or should do, while with other hot-water pipes there is always some gathered here and there.

Every effort should be made to keep these pipes exposed in the places to be warmed. The writer has had to run them in trenches, with gratings over, and behind grated

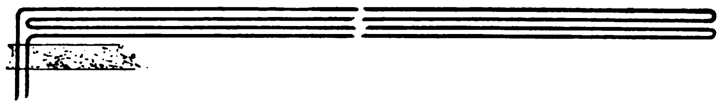


FIG. 174.

skirtings and such other places, but it has always produced a very unsatisfactory feeling. They must be less effective, even when new; they must get loaded with dirt (see church work, p. 87); and, what does not so plainly appear with pipes of a less temperature, the dirt gets heated up sufficiently to give a faintly tainted quality to the air. The dirt being composed of so many materials, such as wool, hair, etc., which give off a little odour when resting on a 300° F. surface, must produce noticeable results. Therefore, endeavour always to have the pipes exposed, so that they may keep clean, or be

kept clean, without trouble. They may be under wall seats, if necessary; but not seats with closed or grated fronts, as the pipes will not then be dusted. Coils under coil cases should be avoided, if possible.

An awkward clause in the London Building Act (which most provincial authorities work to) is that which requires these pipes to be at least 3 inches away from woodwork and all inflammable material, and this applies whether the apparatus has a valve or not. Doubtless the authorities use their discretion in regard to this, otherwise brackets have to project to this extent, if on a wood backing, and pipes through wood floors must come through holes fully 7 inches in diameter.

It is customary when filling an apparatus of this kind, should it be installed in a place of worship or any building which is not heated every day in the winter, to charge it with "frost-defying" liquid. This was originally introduced, and can still be obtained from the firm of W. Stainton, King's Cross Road, London. It is supplied in a concentrated form to admit of its being heavily diluted with water.* Although there are firms undertaking this work who do not consider the use of a non-freezing liquid necessary, yet remembering the smallness of the pipe and the extreme coldness of these large interiors, when left unwarmed for three or four days in wintry weather, it cannot be ignored that frost is very likely to do injury somewhere, if the pipes contain plain water. The greater bulk of water in a low-pressure apparatus affords more resistance to the effects of frost, but even these do not escape always.

Every newly-erected apparatus on completion, whether with expansion pipe or valve, must be tested cold with a suitable hydraulic proving pump and pressure gauge, to 1800 lb. or 2000 lb. to the square inch. This is essential, and no apparatus should have the fire lighted until it has passed this test. It is a quite reasonable one, and ordinary good work will easily stand it.

* For calculations as to the fluid contents of an apparatus of this kind it may be taken that 100 lineal feet of ⅞-inch high-pressure pipe holds a little over 2½ gallons.

A final detail to be explained is the possibility of heating low-pressure radiators by means of high-pressure pipes. This is a plan adopted when the appearance of the pipes of the general apparatus, passing through rooms or places, would be objected to, and where coils in cases, or pipes behind grated skirtings, are equally objectionable. When the heating of radiators by this means was first attempted, the method adopted was to run a high-pressure pipe directly through them, as Fig. 175, but later a better appearance was obtained by the use of a piece of cast tube, through which the heating pipe was carried, as Fig. 176. The radiators are heated by steam, as only a little water is put in them, and the high-pressure pipe brings this to the boil. On first heating up,

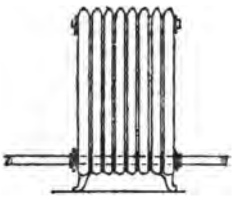


FIG. 175.

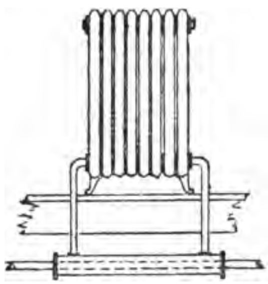


FIG. 176.

an air-cock (having a loose key) on the radiator, is opened until all air is expelled, then it is closed permanently and replenishment is not needed for long periods. As the interior of the radiator must be in a state of vacuum when cool, the boiling of the small quantity of contained water readily occurs at a comparatively low temperature. Of course, if desired, the radiators could be filled with water, if reasonable provision were made for its expanding and for replenishment as it wasted.

The Advantages and Disadvantages of the High-pressure Apparatus.—The advantages are: Cheapness in first cost, provided the pipes do not have to be cased in. It is cheaper than low-pressure hot water, or steam.

Rapidity in heating up (if the circuits are not too long).

This is of advantage in churches, and wherever the apparatus has to be heated up each time the place is used.

Its non-liability to freeze if left out of use in frosty weather; provided, of course, that it is charged with "frost-defying" solution.

The high temperatures obtainable for trade purposes, as in drying rooms, etc. Baking and even japanning can be done in suitably fitted ovens.

The disadvantages that may have an existence are: the absence of any simple means of regulating the temperature of any section of the apparatus. Being an endless tube, stop valves are out of the question, as a valve of the kind could not be closed partially or wholly without stopping the circulation partially or wholly at every point. The absence of stop valves is no objection whatever in large interiors; but in a set of rooms or offices a difficulty might be experienced in getting every room at a temperature that suited the occupants. The sun shining on one room, or a larger number of people being in it, would make it warmer than the others. In a large business premises the writer was once interested in, the pipes were of full proper quantity everywhere, but in those rooms where the temperature occasionally got too high covers were provided to lay over a part of the pipes and thus reduce the radiating surface temporarily. A kind of regulating valve, known as a diverting valve can be obtained, this being a three-way or four-way cock (very heavily constructed for this work) by which the circulation may be diverted more or less (shut off more or less, in fact) without stopping the main circulation. The use of this valve, however, introduces the necessity of branch circulations, and for the proper filling and maintenance of the apparatus these are best avoided until the fitter is well experienced in the work.

The London Building Act, which practically all provincial authorities and insurance companies follow, requires that the pipes be kept at least 3 inches from all woodwork and inflammable material.

The pipes must, or should be, visible. This makes them unsuited for residence work or places where appearance has

to be studied. As previously stated, the pipes may be hidden behind gratings and under cases; but this leads to their becoming loaded with dust, and this, in turn, reduces efficiency and may make an odour or give a taint to the air. It is not quite so bad as some express it, viz. that the pipes if they reach 350° to 400° F. literally fry the dirt, but woollen and hair débris, carrying oils, must be affected.

The apparatus does not admit of alteration, repair, or extension, by any ordinary hot-water fitter, unless he is experienced and actually trained in the work. Even the re-pumping requires a man who knows exactly what is to be done and why he is doing it.

Tables and Rules relating to High-pressure Heating Systems.

QUANTITIES.

Temperature required when it is 30° outside. Degrees Fahrenheit.	Length of $\frac{7}{8}$ in. pipe required to each 1000 cubic foot of space in a brick-built room or place.	Length of pipe in furnace coil, in proportion to the radiating pipe.	Size of expansion tube in proportion to the whole of the other pipes in the apparatus.
50	15	$\frac{1}{12}$	$\frac{1}{9}$
55	19		
60	24		
62	26	$\frac{1}{10}$	
65	28		$\frac{1}{8}$
70	34		
80	50	$\frac{1}{9}$	$\frac{1}{6}$
90	75		
100	110		
110	160	$\frac{1}{8}$	1
120	230		

The reason for increasing the proportionate length of the furnace coil for the higher temperatures is to obtain a greater heat in the water. While water at 300° F. is sufficiently hot for the temperatures required in places occupied by human beings, it is not sufficient to economically afford the higher temperatures required for trade purposes. It may therefore be considered that 300° F. is the maximum for churches and public places, while from 350° to 450° F. will be required for drying rooms, etc.

The sizes of the expansion tubes, too, have to rise in a fixed degree, for although the heat of the room does not affect them, nor is it affected by them, yet they must increase in size with any increase of heat in the water. As their name implies, these tubes are provided to allow for the expansion of the water and, this being so, they would be useless if not large enough. In Box's standard work on Heat the expansion of water is very clearly set out, and giving water at 40° Fahr. the unit figure of 1·00, the following increases in bulk are shown :—

Temperature, Fahr.	Volume.	Roughly over its volume at 40° F.
250°	1·06	$\frac{1}{17}$
275	1·07	$\frac{1}{14}$
300	1·09	$\frac{1}{11}$
350	1·12	$\frac{1}{8}$ (full)
400	1·15	$\frac{1}{7}$ to $\frac{1}{6}$ ($\frac{2}{13}$ths full)
450	1·18	$\frac{1}{6}$ to $\frac{1}{5}$ ($\frac{2}{11}$ths)
500	1·22	$\frac{1}{4}$ to $\frac{1}{5}$ ($\frac{2}{9}$ths)
600	1·31	nearly $\frac{1}{3}$rd

These figures show that with water heated to 300° F. (the maximum for public places) the expansion tube must be large enough to allow of an increase in bulk of one-eleventh at least, and there must be, beyond this, enough space for a

further increase of temperature due to careless stoking and then still have space for the cushion of compressed air. This is why the size of expansion tube for 300° F. work is given as one-eighth the tube, including the furnace coil; for what has to be allowed for is an increase in bulk of the whole of the water in the apparatus. It will also be seen that there is good reason for recommending that a pressure gauge be fitted somewhere in sight of the stoker, so that he may regulate his fire with reasonable nicety.

The temperatures and volumes given on page 260 will show what size expansion tank or cistern should be used when the valve-cistern is adopted in place of the expansion tube. In calculating, allow that each 100 feet of tube holds a little over 2½ gallons, and that therefore with 300° F. work the tank should hold one quart for each 100 feet of pipe, this quantity not filling the tank more than about two-thirds or three-fourths full, as some water should be put in the cistern to cover the inlet of the valve at the commencement.

It may be added to the foregoing that for the high temperatures and pressures that exist with drying-room circulations the expansion tube is always used and not the valve cistern; and it should be the rule to mention the proposed pressure when ordering the expansion tube, as this is the weakest part of an apparatus and it must be of heavier metal when the furnace coil exceeds the one-tenth proportion. It is also customary at these times to test to about 3000 lb. to the square inch instead of 2000 lb. The piping will bear this if the work is properly done.

The tools required for this work have already been partially enumerated, but a list may be given here.

A set of stocks and dies. There is but one size of die, but right-hand and left-hand threads must be provided. The stocks are therefore made to carry the two dies at once, so that either may be used, as required, without changing.

At least three pairs of tongs, two for pipe and one for socket. These tongs are specially long and strong for the work, but what are known as dog-grips may be used if a piece of tube is slipped on the handle to lengthen it.

A tube cutter.

For finishing the ends of the tube, one flat, the other coned,* a common practice is to file the flat or faced end, also to file the outer edge of the coned end. The inner surface of the cone is made with a shop-made tool like a countersink. A small metal square is used for proving the ends of the pipes true.

A forge is needed for all bends, and, of course, a pipe-vice must be provided.

A force pump for filling.

A proving pump, with pressure gauge, for testing.

The usual bag tools, such as a hammer, screw-wrench, and screw-driver are often needed, also the tools for the brick-setting of the furnace coil.

* It is customary to face the end with the right-hand, and cone the end which has the left-hand, thread.

CHAPTER XVI.

WARMING BUILDINGS BY HEATED AIR.

This Subject has to be divided into two parts, viz.: Warming by air that has received heat by passing over encased hot-water (or steam) radiators; and Warming by stove-heated air.

WARMING BY AIR HEATED BY HIDDEN RADIATORS; KNOWN AS "INDIRECT HEATING."

IT must first be explained, as clearly as possible, that in indirect heating the radiators or heating surface do nothing towards re-heating the air that is already in the room, and they afford no direct heat by radiation. When radiators are fixed in rooms they give some heat by radiation and still more by warming the air already in the room, but in "indirect" work neither of these heating effects exist. Indirect work is the warming of fresh air in a suitable chamber or enclosed space and the subsequent delivery of this air into the room. The enclosed space may be near or a distance away, and the air may pass to a single room or several apartments.

It naturally follows that if the warmed air, which is to make a room comfortable, receives its heat away from the room, some power must exist or be provided to bring the air to the room, and to bring it in a regular positive stream. This is the important detail in connection with indirect heating, as the desired warmth can only be had by causing the air to flow through the room continuously. There must be new warmed air always entering and a corresponding volume of cooled and vitiated air departing, and this means—provision for effective ventilation. Indirect work is therefore

little more than ventilating work with a means of warming the incoming air; but as the fresh air is relied on to bring warmth, its flow must be positive and regular, which requires that the ventilating scheme must be quite reliable in its operation. It follows that if the air movement is more or less a failure or uncertain, the warming of the place must suffer accordingly.

Fig. 177 illustrates an indirect radiator, built up of sections nippled together, and its size may be anything according to the work to be done. The ordinary type of radiator is not used for this work, as the spaces between the sections are too open to admit of the air being properly warmed as it passes through. To effect the warming of the air the radiator sections are given gills (or webs or pins), so that the finished

FIG. 177.

article may be said to resemble a strainer or filter, as the air spaces, while allowing a fully sufficient flow of air, are so contracted as to cause practically all the air to rub against the hot surfaces. These gills, too, are extensions of the heating surface, so that the space occupied is less than it would be if the radiator were built up of tubes with plain surfaces. As stated, some indirect radiators have the tubes gilled, as shown, while others are thickly pinned or have short ribs arranged on the surfaces. In all cases the results aimed at are alike.

Fig. 178 shows the radiator fixed in position. Four rods of ½-inch iron, with screw holes at the ends that are secured to the joists and hooks at their lower ends, carry two pieces of ½-inch or ¾-inch tube placed horizontally, and on these the radiator will securely rest. Suspended in this way it will, too,

give to the movements of expansion and contraction, should there be any. The whole is encased with a wooden box casing, this being lined with zinc or galvanized sheet iron. Occasionally a surrounding of wire netting is adopted, this being plastered over, but there is not such a certainty of this remaining sound and air-tight. In many instances it is important that the casing be air-tight, as its situation may be at a point where the surrounding air is not sweet. In one instance the writer had to make such a casing at the ceiling of

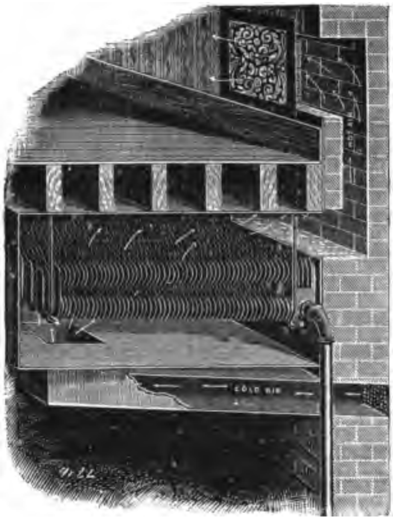


FIG. 178.

a kitchen, and it followed that had there been a fissure the odours of cooking would have been delivered with the warmed air.

The fresh air is brought by an air-tight tube (of any shape) from the nearest source where it can be had pure and untainted, and it should enter the radiator chamber at a point as remote as possible from the warm air outlet.

The warm air outlet is customarily arranged to come in the wall as illustrated, the air entering the room through an adjustable grating known as a "register." These registers

can now be had in very beautiful designs and in every required size. The mechanism which controls the flow of air through the register too, is very ingenious, yet simple and not likely to get out of order. Occasionally the warm air outlet, and its register are arranged to come in the floor, over the middle of the radiator or thereabouts. This is a cheaper arrangement as a rule, but has the great disadvantage of causing the radiator to become loaded with dirt in a short time. Servants have even been known to purposely sweep dirt through floor registers to save the trouble of using a dust pan.

It was just stated that the warm-air register had mechanism to adjust the flow of air, but, although there may be occasions when it is desirable to use this, it is not a good plan to reduce the warmth of the room by it. If a room should be too warm, by reason of the water being too hot, or the sun shining on the room, or an extra number of people being in it, then it is better to reduce the temperature of the incoming air rather than reduce its volume. To effect this a "mixing damper" may be used, this being a simple device by which part of the new air can come through the radiator chamber without passing through the radiator, and mixing with the warmer air as it flows through the register into the room. Fig. 179 illustrates this, and it will be seen how simply the valve can be controlled from the room.

Radiators used in this work are connected up on any of the piping systems described in this book, and each radiator should be provided with stop-valve and air-cock, both these coming outside the casing. All radiator cases or chambers should have a door or similar opening by which access to the radiator may be had for brushing and cleaning the heating surfaces.

It will be understood that one radiator, if of suitable size, can be arranged to heat two or more rooms. When this is done rooms are generally chosen which come over one another, so that a warm-air tube or duct may go straight up the wall (on the face of the wall or chased in) with registers opening into the rooms on the different floors. The duct in this case

commences in a full size and is reduced as it passes each register. This will be found illustrated a few pages further on, and the sizes are fixed by the rule that is about to be given.

In making warm-air chambers, as just described, the sides may come fairly close to the radiator, but beneath the radiator the least depth should be 6 inches, while the space above should not be less than 8 inches.

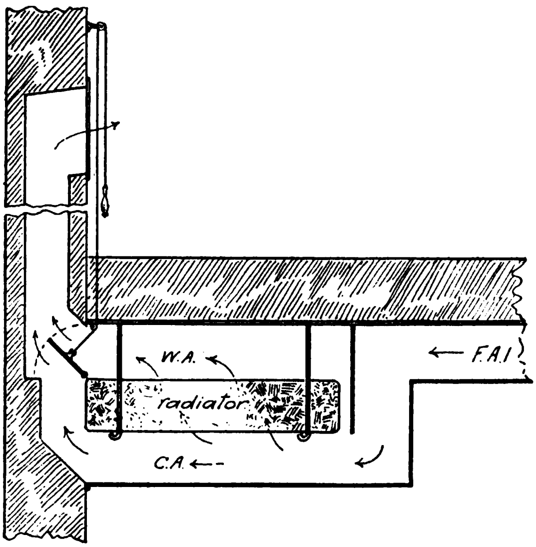


FIG. 179.

In regard to the heating surface required to afford certain temperatures, the table on p. 106 may be taken and 50 per cent. added to it. It is the rule in this work to add one-half, so that a room which would be heated to 62° F. by 16 feet of direct radiator surface per 1000 cubic feet of space, must be provided with 24 feet of indirect surface to obtain the same result. There are two reasons for this great difference. One is that a room heated by indirect radiation has more changes of air—which means that it is cooled more—than rooms which are not specially ventilated, and the radiator is the thing that has to make good the cooling

influence, and cannot escape it. The other reason is that indirect radiators are not all prime surface. Gills, pins and solid projecting parts, though not projecting far, are not true prime surface. The latter is usually considered to be that which has water immediately against one side of it and not separated from the outer surface by more than a quarter-inch of metal or less. By increasing the area of outer surface to quite double that of the inner heat-receiving surface there must be a diffusion of heat and a reduction in temperature. This arrangement serves excellently for heating air, but it is not so efficient in affording warmth as prime surface, and hence the 50 per cent. total allowance.

For indirect hot-water work the warm-air delivery tubes or ducts should have an area of 2 square inches for each square foot of surface in the radiator; thus a 50-foot radiator would have a delivery duct of 100 square inches, equal to, say, a 12½-inch by 8-inch tube. At the point of delivery the warm-air duct should open out and be fitted with a register which has a clear space through it of about one-fourth greater area than the duct. Registers, as a rule, have a clear opening of about one-third less than the face measurement of the grating. A good make of register (examined by the writer), measuring 12 inches by 16 inches across the grating, had 128 inches of clear space, and this would be the size for the 100 square inch duct just mentioned.

When a radiator and its warm-air chamber are arranged to heat more than one room, then the size of the duct and its reductions in size may be calculated on the following basis. For the area of radiation allowed to the ground floor the duct should have an area of 2 square inches per foot of radiation (as already stated); for the first floor, 1¼ to 1½ square inch per foot; while for a second floor, 1 square inch per foot is sufficient. A duct, like a chimney, has the velocity of its draught increase rapidly with its height, and the reduction in area this admits of is not only a saving in cost, but is necessary to prevent the upper floors taking an undue share of the air.

The cold-air supply duct or tube should be three-fourths the area of the warm-air duct, or three-fourths the total area

of all warm-air ducts if there is more than one. The reason for making the fresh-air duct of this area, the warm-air duct larger, and the register opening still larger, is partly to allow for the warmed air becoming expanded and being of greater bulk; but, more important, it is to reduce velocity of discharge through the warm-air registers. The flow of warmed air into the rooms should be gentle and unnoticeable.

There are no obstacles to the fixing of indirect hot-water radiators as regards their proximity to woodwork or inflam-

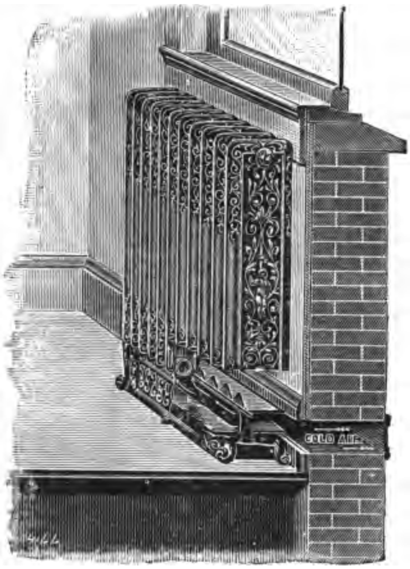


FIG. 180.

mable material; nor are the warm-air ducts from these subject to any vexatious regulations by local or other authorities, nor are Fire Insurance policies affected in any way. These things are mentioned, as quite the reverse applies with warm-air works when the heater is a stove (see extracts from London Building Act, in Appendix).

For particulars relating to outlet flues or ducts, which carry off the cooled and vitiated air, and which are essential to the proper working of an indirect heating apparatus, the

reader is referred to the next section of this subject, which relates to warming by stove-heated air. The reader is recommended to read that section through, as there is much that relates to both, particularly the part dealing with ventilation.

In concluding the subject of warming air by hot-water radiators, a short description may be given to the "direct-indirect" or "ventilating" radiator. This is a radiator devoted to warming a current of fresh air which is continually passing through it, but the radiator itself is fixed and visible in the room, and affords radiant heat and does something towards re-heating the air contained in the room. As a rule the base of the radiator is so arranged that the flow of fresh air can be partially or wholly shut off, and the radiator made to partially or wholly heat and re-heat the air already in the room.

FIG. 181.

Fig. 180 illustrates a radiator of this kind, with its fresh-air inlet at the back close to the floor. They can also be had with extreme bottom inlets for the air to come up vertically from below. The sections of these radiators are of a design that, when connected up, forms a number of vertical air flues up through the radiator, so that the incoming air cannot pass into the room by any short route, but must be warmed by intimate contact with the heated surfaces. Fig. 181 illustrates the base casting of the radiator, looking on top of it, showing the front and rear valves, which, as previously stated, allow either new air, or the air of the room, to partially or wholly pass up through the radiator.

These radiators are also connected up on any of the ordinary piping systems, and are furnished with stop-valves and air cocks in the usual way. Where there is a difference, it

is in the amount of heating surface required to afford certain temperatures. The method employed to find this is to work to the table for direct radiation, on page 106, and add 25 per cent. to this. This additional surface is needed to allow for the room having more changes of air than rooms usually have when not specially ventilated, and the fact that the radiator receives the air first hand when it is at its coldest.

Outlet (i.e. extract) ventilation is as necessary for the efficient working of these radiators as it is with indirect work, and the reader is referred to the next section of the subject, viz. : warming by stove-heated air, for the detail of this.

WARMING BY STOVE-HEATED AIR.

There is, in English minds, a prejudice against this mode of heating, a prejudice which probably had its origin in the use of the "Cockle" stove, many years ago. This was a stove made expressly to warm air, but which readily allowed its air heating surface to become red-hot, with the result that the air delivered into the rooms had a distinctly ill effect on the occupants. Of course no such stove is made or used for this purpose now. Prejudice may have arisen, also, with some experience* of a stove which admitted of over-heating by over-firing, but those who make stoves for this work now know what limit to put to the area of fire bars to prevent excessive heating.

Briefly explained, this method of heating is effected by providing a suitable stove (of which there are several made expressly for the purpose) which is either enclosed in a brick chamber, the air circulating between the stove and the surrounding brickwork ; or the stove has an iron casing and the air passes between the two. Leading into the air space around the stove there must be a fresh air tube or conduit, while from the air-warming chamber there are carried one or more warm-air tubes or ducts which deliver the warmed air where it is

* It is remarkable how prejudice against any mode of heating is seldom based on experience.

required. The warm-air ducts terminate in gratings, called "registers," usually in the walls of the rooms, as shown in Fig. 178 and described on p. 265.

What has to be particularly pointed out—and this was not dealt with in the earlier section of this chapter—is that no system of heating by warmed air can be at all effective if there is not a positive system of extract ventilation provided.

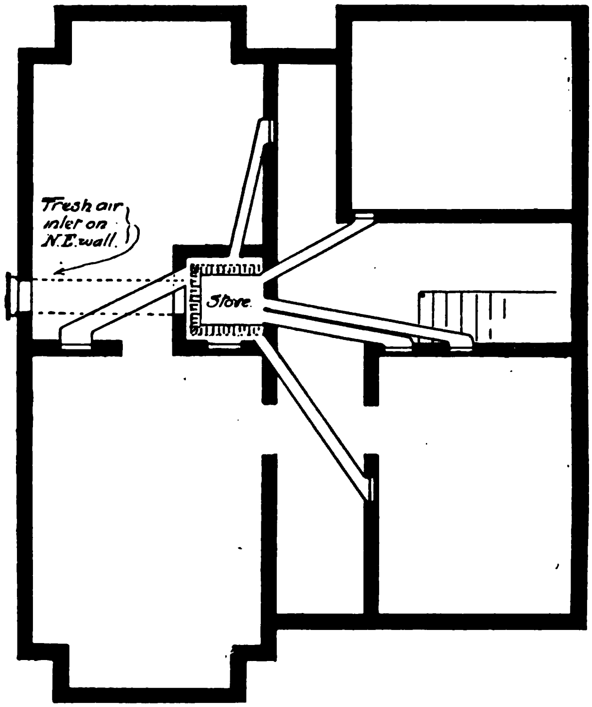


FIG. 182.

Air, warm or cold, will not enter a room which is already full of air and where there is no active extraction of existing air occurring. Put in another way, the inflow of air into a room is in a fixed proportion to that which is taken out. The taking out (extraction) of air from a room is in fact the cause of the new air entering, and one is absolutely essential to the other. It is important that stress be put upon this, as there is

a rather widespread impression that warmed air will ascend and flow into a room of its own accord, which impression proves to be quite wrong if applied to a warm air heating installation. It may therefore be repeated that there must be a regular withdrawal of air from a room to ensure a regular inflow of new air, quite apart from the fact that it is desirable to withdraw air which has become cooled, vitiated, and objectionable.

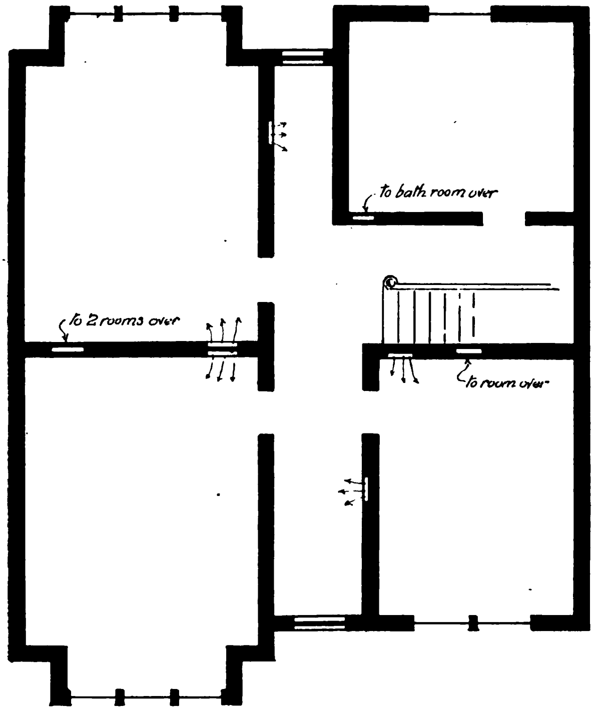


FIG. 183.

In Figs. 182 and 183 an example installation is shown the first illustration being the cellar plan ; the second being the ground floor, showing the registers there and the ducts which lead to the floor above. The description of the apparatus may be given in the character of a specification as follows :

Heater.—The heater or stove should be of full capacity as

to heating surface, which does not then require to be raised to too high a temperature to afford the required degree of warmth to the full volume of air. This also saves making very bright fires, which shorten the life of its wearing parts. There is also a distinct saving in the labour of attendance. The heater is best located so as to provide the shortest and most direct runs for the horizontal warm-air ducts, and to keep them of as uniform length as possible. If there is any difference, and if it is possible, the ducts which go the highest should be the longest horizontally. The location of the heater should also be arranged with a view to easy access and convenience to the fuel store. The heater, whether with metal or brick-built air chamber, must be absolutely air-tight in its fixing, so that no communication, however small, exists between the cellar and the cold or warm-air ducts. In other words, the registers should not discharge a mixture of fresh air and cellar air. The heater must be of a kind expressly made for this work, and which has its exterior gilled so as to extend the heating surface and keep it at a comparatively low temperature. This is explained on p. 4. Fig. 184 shows a heater made by Musgrave & Co. There should be access to the space around the heater—the warm-air chamber—for cleaning purposes. This would be by a doorway or other opening, which must be made to close or fit air-tight. All stoking is done from outside the air chamber, the front of the stove coming flush with the exterior, as Fig. 184 shows.

Cold-air Duct.—This may be of earthenware pipe with cemented joints (if the job is small enough) or of stout matchboarding lined with sheet zinc or iron. In certain cases it may be found best to build it in brickwork, cemented inside. The duct enters the chamber as close to the bottom as possible, but may be carried overhead across the cellar if desired. Fig. 185 shows this. In Fig. 184 the fresh air is shown entering beneath the stove, and there is much to be said in favour of this. It is not always possible, however, as it means carrying the duct, or part of it, beneath the cellar floor, and this may make access for cleaning difficult to obtain. Cold-air ducts should have openings for cleaning purposes, these openings

having soundly fitting doors. The grated entrance to the duct should be lined with wire gauze of a sufficiently small mesh to prevent the entrance of insects and particles of dirt material. The use of the gauze obstructs the air way and

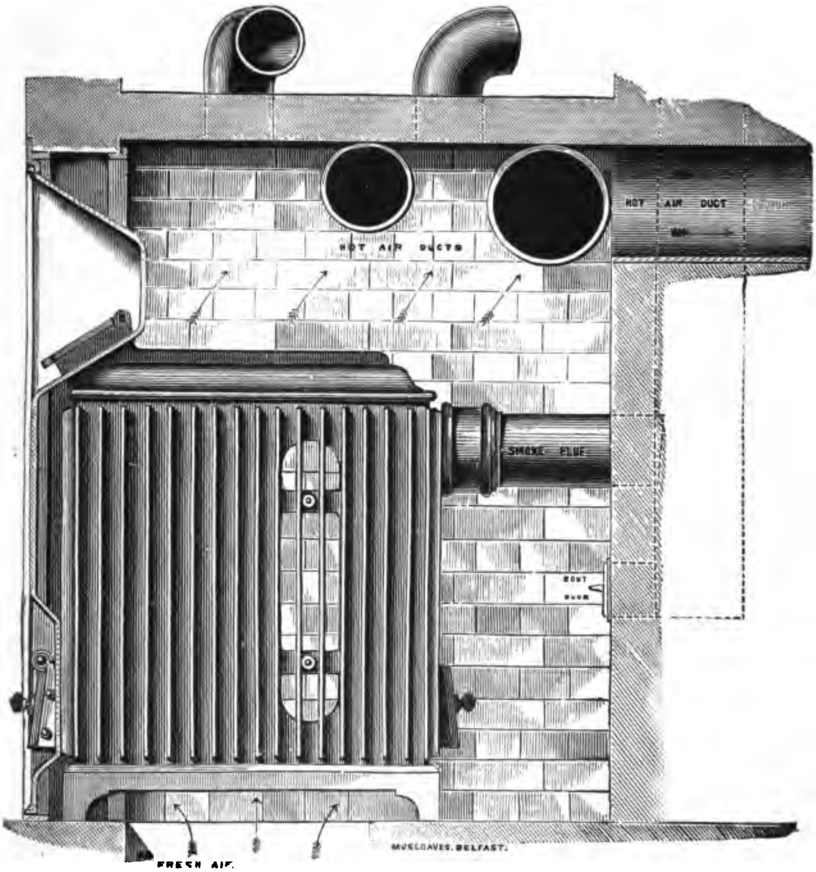


FIG. 184.

makes it necessary to considerably enlarge the grated entrance. Allowing for the solid parts of the grating and the gauze lining, the area of the grated entrance should be double the area of the duct.

American heating engineers, most of whom make a specialty of this work, commonly provide duplicate cold-air ducts, each of full size, one opening on, say, the N.E. wall and one on a S.W. wall, or the walls that face nearest to these points, and provision is made to use either as desired. The reason for this is that the wind may materially affect results with a single duct, by either exerting a pressure when blowing on to its exterior opening, or an exhausting effect when it is against

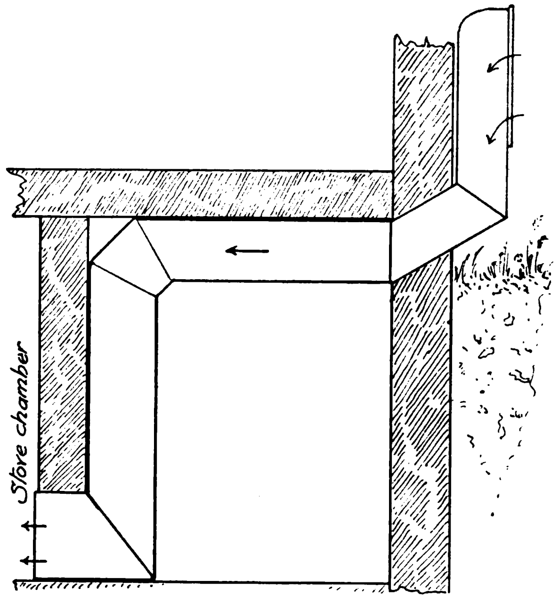


FIG. 185.

the opposite side of the house and thus blowing from the direction of the opening. The single duct is the rule with work carried out in England, but it should be in a position sheltered from the wind when blowing towards it.

Air Filter.—If found necessary or desirable the air can be filtered, this being effected by causing it to pass through a thin layer of cotton-wool, or through muslin or cheese-cloth. Fig. 186 shows a method of doing this, but the filtering material

offers so much resistance to the passage of air that it should be at least six times the area of the duct. When using this the wire-gauze lining to the grated entrance may be dispensed with, if desired, the grating itself or a piece of $\frac{1}{4}$-inch mesh wire netting being usually sufficient. When muslin is used it is simply stretched in a frame, but if wool is used it must be a thin layer between two pieces of wire netting secured in a frame. It is important that access be had to this filter

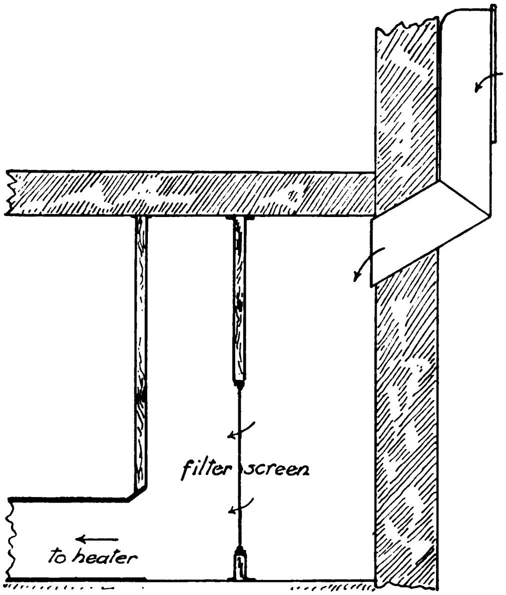


FIG. 186.

screen, or provision be made for sliding it in and out, for all filters are simply dirt-collectors, and the filtering material must be brushed or renewed occasionally. What particularly hastens the clogging of filtering material is moisture in the air. In times of fog or mist the filter will get loaded with water vapour, and this mats and clogs the pores badly. A filter should, therefore, only be used when the air really needs filtering, as, otherwise, it is a source of probable annoyance

unless a skilled attendant is on the premises. It is never wanted in the country, and only in manufacturing districts or places where the air carries dust or dirt in unusual quantities, is filtration so beneficial as to become a necessity. For certain trade purposes, as in supplying hot dry air to a laundry drying room, a very clean air may be requisite, and filtration resorted to with ordinary town air.

Evaporating Pan.—A surface of water of an area of one square foot would provide the necessary moisture to an apparatus of the size being described, this making it of normal humidity. The pan has to be in the heating chamber, but the water must be replenished from the outside. A feed cistern, either hand fed or with a ball valve, can be arranged to effect this, it only being necessary to mark the normal water level in the cistern to see at a glance if the pan inside is supplied. The evaporating pan inside must be disposed where it will most readily furnish moisture to the heated air which is rising from the stove. It must not touch the stove or the water may boil. This must be avoided.

The writer does not know of any fixed rule by which the area of water in an evaporating pan can be decided by the area of heating surface, but any simple form of hygrometer may be used to settle this, remembering that the air should have not less than 60 per cent. and not more than 80 per cent. of its full moisture when saturated (see table in Appendix). If the air has less than 50 per cent. of its full moisture it is too dry and will commence to rob the body, reduce its temperature, and lower vitality. If the air is too moist it is plainly noticeable and it has a depressing and general ill effect. A very agreeable percentage, as occurs naturally outdoors in the summer months, is about 70 per cent.

Warm-Air Ducts.—In the illustration, Fig. 182, a separate warm-air duct is shown taken from the heating chamber to every possible point, and this is the usual and best plan in works of this size and character; but, if considered requisite, the warm air may be conveyed through one main duct, branched where required, as Fig. 187. This represents, in plan, a horizontal duct serving four registers. Warm-air

ducts may be of earthenware pipe with cemented joints, or of galvanized sheet iron. In the latter case it is generally necessary to coat them with some poor heat-conducting material. Quite apart from the heat loss that must occur from sheet metal pipes in cellars, there is the probability of the cellar air, when warmed by bare pipes, working its way up through the house. Cellar air may not be impure, but it is not what is expected with a warm-air apparatus.

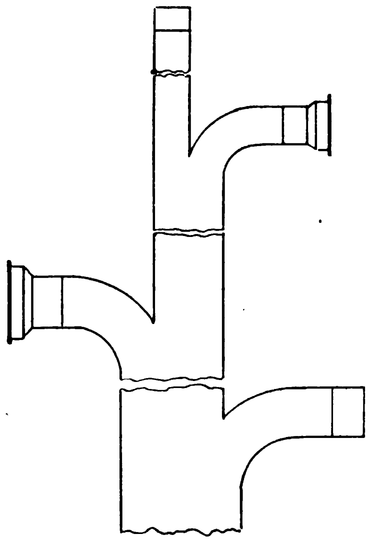


FIG. 187.

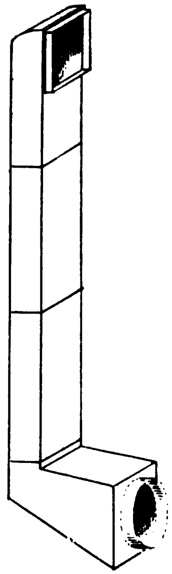


FIG. 188.

The registers through which the warm air is delivered into the rooms give the best results if situated opposite to the exposed or coldest parts of the rooms. All warm-air ducts should be given a slight rise from the heating chamber, say 1 inch in 10 feet. The making of warm-air ducts calls for rather good whitesmith's work, as although the horizontal cellar pipes may be round, there has to be a change in shape when the duct passes into the wall. Fig. 188 gives an idea of this. In a new building these ducts can be provided in brickwork in the thickness of the walls, as the illustrations Figs. 182 and

183 show, but failing this, metal tubular ducts must be chased into the wall or run up on its face. In America the authorities allow sheet metal ducts to run up in lath and plastered (studded) walls, but no English authority will allow this (see extracts from London Building Act in the Appendix).

Registers.—The gratings of registers in all good rooms should be of nice design and appearance. There is no difficulty about this, as quite a wide choice can now be had in most factors' catalogues. Fig. 189 shows an example from the American Radiator Co.'s catalogue. All registers must have opening and closing mechanism by which the passage of air

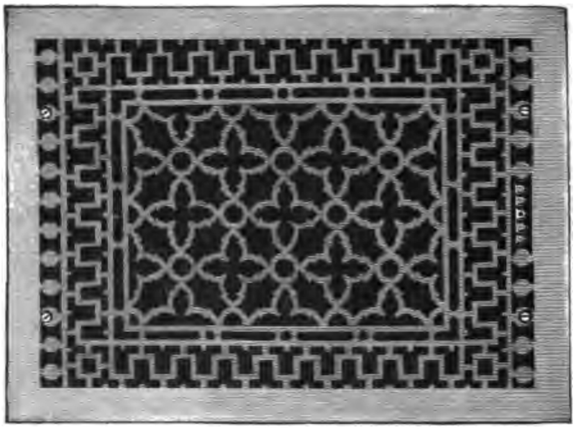


FIG. 189.

may be adjusted and controlled; it must be possible to set them, so that they will remain set, at any point between open and shut. As already stated, registers should be in walls and not in floors. The latter commonly entails the least work and expense, but a grating in a floor favours a collection of dirt in the duct and tempts the servants to sweep dirt into it instead of picking it up. This may result in vitiating the air. Floor registers have to be used sometimes however, as a wall register may be in too close proximity to woodwork.

Extract or Ventilating Shafts.—In the relative sizes of ducts, etc., given further on, the comparative areas for the

inlet and ventilating shafts are included, and for residence work this may be worked to without considering the number of people that may be occasionally gathered in a room. When, however, the work is in public places, institutions, schools, etc., it is necessary to consider the number of occupants, and furnish a supply of new air and remove a volume of vitiated air that amounts to so much per head. Referring again to residence work, or the like, there are usually brick-built chimneys to all the principal rooms in a house, and these serve excellently as extract ventilating shafts, assuming they have a normal up-draught in them. If, however, a house or place was built expressly to be warmed by heated air, and chimneys were dispensed with, then ventilating shafts would have to be provided as a detail in the building construction, and the rule that is given on p. 283 should be worked to. Ordinary chimneys may be said never to err on the side of being too small to ventilate any room in a residence, and it is only when ducts for the vitiated air have to be made or built expressly that their size must be calculated.

When the extraction of cooled and vitiated air and the supply of new warmed air has to be calculated at per head, then the two following tables must be worked to:—

CUSTOMARY VOLUMES OF AIR ALLOWED PER PERSON IN INSTITUTIONS AND PUBLIC PLACES.

	Cubic feet per minute.
Schools, infants	28 to 30
„ scholars of full age	30 to 32
„ dormitories	25 to 28
Workrooms, slight exertion, air not vitiated by the trade followed	35 to 40
„ full exertion	45 to 50
Public halls, meeting rooms	35
Ball rooms	45
Theatres, dining halls	35
Hospitals, ordinary wards and rooms	45

VOLUME OF AIR IN CUBIC FEET EXTRACTED PER MINUTE BY A VENTILATING SHAFT OF ONE SQUARE FOOT AREA.

No allowance made for friction; deduct 35 to 50 per cent. for this, according to height and size of shaft.

Height of Ventilating Shaft in Feet.	Excess of Temperature of Air entering the Ventilating Shaft, above the External Air.					
	5°	10°	15°	20°	25°	30°
10	116	164	200	235	260	284
15	142	202	245	284	318	348
20	164	232	285	330	368	404
25	184	260	318	368	410	450
30	201	284	347	403	450	493
35	218	306	376	436	486	531
40	235	329	403	465	518	570
45	248	348	427	493	551	605
50	260	367	450	518	579	635

It is requisite to mention that a ventilating shaft must have the same consideration as a smoke flue in regard to its upper termination. Although the table may show that a short shaft will meet the requirements, still it must go to the top of the building and up above its highest ridge. If not, it will suffer with down-blow or retarded up-draught (when certain winds are blowing), the same as a fireplace chimney. A ventilating shaft must be considered as a chimney in regard to its height and those conditions which ensure its having a permanent up-draught of regular speed.

If these shafts are built in brick-work during the construction of the building, they may be carried up separately and terminate either singly or in stacks as brick chimneys do, but if a hot-air apparatus is installed in an existing building and the heating engineer has to provide metal ventilating shafts, then it is the custom to connect several, or all of them, into

one main shaft (which usually runs along or through the attic or roof space), and carry this up and out like a chimney. It would not be possible, nor sightly, to carry a number of single metal tubes up through a roof. In certain necessary cases a gas ring is put in the base of the main shaft (to stimulate the draught) or a mechanically driven air propellor.

RULES FOR CALCULATING SIZES OF COLD AND WARM AIR DUCTS, REGISTERS AND VENTILATING SHAFTS. Residence or similar work only, in which each person has about 400 cubic feet of space. For institutions see p. 281.

Heaters, 8 to 9 square feet of heating surface per 1000 cubic feet of space in the rooms to be warmed. This allows for a low temperature heating surface.

Warm-air ducts to ground floor, 50 square inches area per 1000 cubic feet of space in the rooms to be warmed.

Ditto, ditto, first floor, 40 square inches.

Ditto, ditto, second floor, 32 square inches.

Cold-air duct to stove chamber, three-fourths the total area of the warm-air ducts.

Grating to cold-air duct, if lined with wire gauze, double the area of the duct.

Registers or gratings in rooms, through which the warm air is delivered, one-fourth greater area than the warm-air ducts which serve them. This ensures the gentle delivery of 3 feet to 4 feet of air per second, and causing it to spread out as it enters. The area of a register grating is that of the open spaces in it. The metal portion averages one-fourth to one-third, the latter most usually (see table in Appendix).

Extract ventilating shafts or ducts, which carry off the cooled and vitiated air, ground floor 32 square inches area per 1000 cubic feet of space in the room.

Ditto, ditto, first floor, 40 square inches.

Ditto, ditto, second floor, 50 square inches.

Registers or gratings of ventilating shafts, the same area as the shaft, but this area must be that of the open spaces of the grating. The metal portion averages one-fourth to one-third, the latter most usually (see table in Appendix).

Areas of round pipes (for cellars) can be ascertained by deducting one-fifth of the area if square; thus an 8 × 8 inch square pipe has 64 square inches, while a round pipe of 8 inches diameter would have nearly 51 square inches.

The following is a simple rapid table for round pipe:

Diameter of round pipe.	Will serve a ground floor room.	Will serve a first floor room.
inches	feet	feet
8	10 × 11	12 × 12
9	12 × 12	12 × 15
10	12 × 14	14 × 17
11	14 × 16	16 × 18
12	15 × 18	18 × 20

A 7-inch pipe may be used for cloak rooms, small bath rooms, etc.

There now remains to be described a means of arranging for a hot-air apparatus to either heat a continuous stream of new air (as already described) or to partially or wholly heat and re-heat the air already existing in a place. In schools, places of worship, public halls, and the like, which have to be warmed some time before they are occupied, there is effected an economy in fuel and, particularly, an economy in time, if the apparatus is first devoted to heating the air contained in the place without heating a stream of new cold air all the time. It will be seen that there is no occasion for a full and constant change of air when the place is unoccupied, and the trouble experienced in all public places which have to be heated up each time they are required for use is the long time taken in getting the required warmth. Again, there are places which have a varying number of occupants, and if the ventilating arrangements are suited for the maximum number, there is no reason why this should not be checked and the contained air partially re-heated when the number of occupants is much below the maximum. This economises fuel and labour.

Fig. 190 shows how this can be done, while Fig. 191 gives, in plan, a suggestion that might be adopted in a place of worship, this showing the warm-air ducts and the return duct by which the contained air comes back to the heater. This latter need not be in the floor, and it is best to avoid floor gratings, as they favour a rapid collection of dust in the duct, which may rarely be cleaned out. The floor gratings are shown here more to make the illustration clear than to recom-

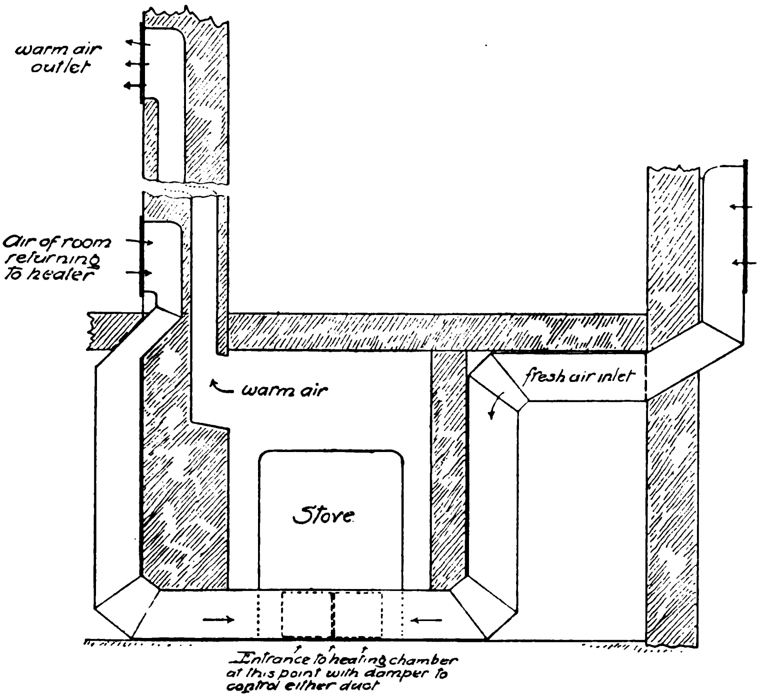


FIG. 190.

mend them, and it would be a better plan to let a return duct come along each side wall beneath the warm-air ducts, as in Fig. 190. In public places, particularly those with high interiors, it is distinctly best to have the warm air entering two or three feet above the breathing line, and this will be found to act well in reducing, if not obviating, the down currents of

cold air so often experienced in such places, notably in churches. (See Church Work, p. 89).

With regard to the disposition of the inlet and outlet registers in rooms, there has always been some difference of opinion as to the best points at which these registers should be situated to ensure a thorough circulation of air at all parts

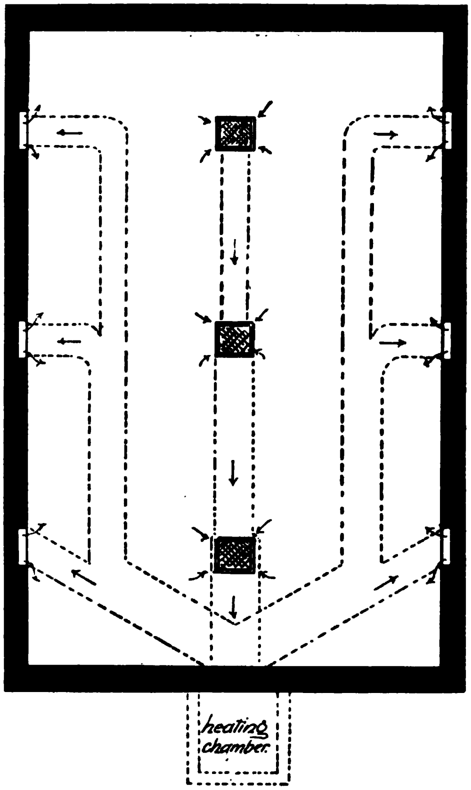


FIG. 191.

of the room. When *cold* air is admitted into a room there can be no doubt that it should come in at a low point, and the vitiated air, which is of a higher temperature, will best get away from overhead; but this is summer ventilation, and the conditions when a place is being heated by warmed air are practically reversed. It may be considered, in fact, that

whether the heating be indirect (warm air) or direct (with exposed radiators), the vitiated air is best removed from a low point. Warmed air is lighter than warm products of respiration or combustion, and these latter readily descend and pass away near the floor level. This also carries down dust arising from the floor.

Owing to the conditions in a place warmed by hot water or heated air being, in a sense, reversed in summer and winter, it is recommended, when it is possible, that each inlet and outlet register be duplicated. Let each duct extend up the full height of the wall of the room and have one high register and one low. The warm-air duct would have one about 7 feet to 8 feet high* and one near the floor, while the outlet duct would have one near the ceiling and one near the floor. In winter the highest warm-air register and the lowest outlet register would be open, while in summer (for cool air ventilation) the highest outlet and lowest inlet would be in use.

Warm air inlet registers are best situated on inner walls and facing outer walls; in other words, the warm air should be discharged towards the exposed part of the room. The outlet register is also best on the same wall, either in a line beneath the other or within a yard of this. The old practice was to get the registers as remote from one another as possible, but this has been clearly proved to favour air currents instead of a circulation and general air movement.

In Fig. 192† is shown the result of some experiments carried out to ascertain the best and worst points at which registers might be fixed. The experiments were conducted in a small room—a model schoolroom—the warmed air being made visible by smoke. The best results were obtained with the registers both on one side of the room, as just recommended. Air introduced at a greater velocity than usual might alter these results, but in warm-air work the velocity should never exceed 5 cubic feet per second, while 3 feet to 4 feet is decidedly better, as stated on p. 283.

* It should have been mentioned before that when it is decided to fix the warm-air registers high and the extract registers low, the former should not be less than 6 feet high, higher for preference.

† From Carpenter's "Heating and Ventilating Buildings."

It is important that the sections of the London Building Act which relate to stove-heated air work be studied (see Appendix which follows), as, although this Act may only refer to the London district, yet most provincial authorities consider

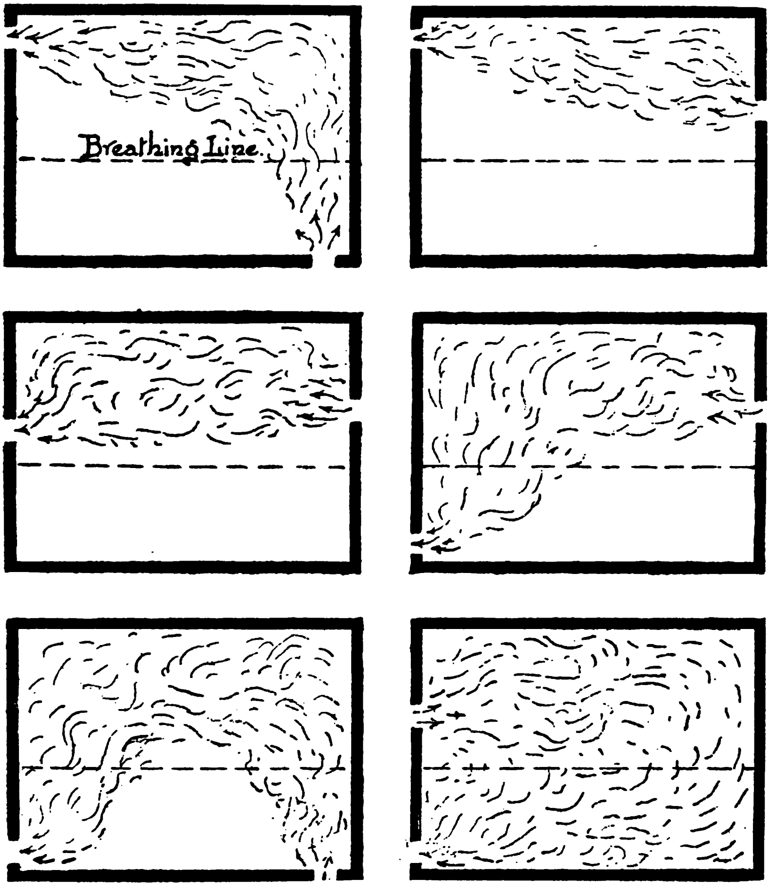


FIG. 192.

it a correct model to work to in a general way. Any deviation from the regulations imposed by this Act may, too, affect the value of any existing fire insurance policy or the cost of its premiums.

APPENDIX.

EXTRACTS OF SECTIONS FROM THE LONDON BUILDING ACT, 1894, RELATING TO WORK EXECUTED BY HEATING ENGINEERS.

"The jambs of every fire-place opening shall be at least eight and a half inches wide on each side.

"The breast of every chimney and the brickwork surrounding a chimney shall be at least four inches in thickness.

"A party wall at the back of every fire-place opening from the hearth up to a height of twelve inches above the mantel shall be at least eight and a half inches thick. [*This is insufficient if a skirting board, or dresser, or other woodwork is on the other side. The heat from a bath boiler flue will char it. One inch of silicate cotton should be inserted in such cases.*—F. D.]

"There shall be laid level with the floor of every storey before the opening of every chimney a slab of stone, slate, or other incombustible substance, at the least six inches longer on each side than the width of such opening, and at the least eighteen inches wide in front of the breast thereof.

"On every floor except the lowest floor such slab shall be laid wholly upon stone or iron bearers or upon brick trimmers or other incombustible materials, but on the lowest floor it may be bedded on concrete covering the site or on solid materials placed on such concrete.

"The hearth . . . . shall be solid for a thickness of six inches at least beneath the upper surface of such hearth.

"A chimney breast or flue shall not be cut into except for the purpose of repair or during some one or more of the following things:—

(*a*) Letting in or removing or altering flue pipes or funnels for the conveyance of smoke, hot air, or steam, or letting in, removing, or altering smoke jacks.

(*b*) Forming openings for soot doors, such openings to be fitted with close iron door and frame.

(*c*) Making openings for the insertion of ventilating valves subject to the restriction that an opening shall not be made nearer than twelve inches to any timber or combustible substance.

"Timber or woodwork shall not be placed :—

(*a*) In any wall or chimney breast nearer than twelve inches to the inside of any flue or chimney opening.

(*b*) Under any chimney opening within ten inches from the upper surface of the hearth of such chimney opening.

(*c*) Within two inches from the face of the brickwork or stonework about any chimney or flue where the substance of such brickwork or stonework is less than eight and a half inches thick, unless the face of such brickwork or stonework is rendered.

"Wooden plugs shall not be driven nearer than six inches to the inside of any flue or chimney opening, nor any iron holdfast or other iron fastening nearer than two inches thereto.

"The floor under every oven, copper, steam-boiler or stove, which is not heated by gas, and the floor around the same shall for a space of eighteen inches be formed of materials of an incombustible and non-conducting nature not less than six inches thick.

"A pipe for conveying smoke or other products of combustion, heated air, steam, or hot water, shall not be fixed against any building on the face adjoining to any street or public way.

"A pipe for conveying smoke or other products of combustion shall not be fixed nearer than nine inches to any combustible materials. [*It is as well to exceed this distance when carrying sheet iron pipe beneath ceilings or near light woodwork, for should the pipe have its soot catch alight it may get red hot.*—F.D.]

"A pipe for conveying heated air or steam shall not be fixed nearer than six inches to any combustible materials (*see below*).

"A pipe for conveying hot water shall not be placed nearer than three inches to any combustible materials (*see below*).

"Provided that the restrictions imposed by this section with respect to the distance at which pipes for conveying hot water or steam may be placed from any combustible materials shall not apply in the case of pipes for conveying hot water or steam at low pressure.

"For the purposes of this section hot water or steam shall be deemed to be at low pressure when provided with a free blow-off. [*This qualifying clause gives liberty to run ordinary low pressure hot water pipes close against woodwork, as is commonly done; but with*

a low-pressure gravity steam apparatus working at 5 lbs. to 10 lbs. pressure, returning its own water to the boiler, and being therefore closed and having no free blow-off, a six-inch limit must be observed. This is not reasonable, as a low-pressure hot water apparatus extending up say fifty feet, can have its water raised to a higher temperature than 10 lb. steam. Again, an exhaust steam apparatus with a free blow-off may oftentimes be served with steam at a much higher temperature than that in a low pressure closed gravity circulation. It will be seen that small bore hot water pipes (high-pressure or with valve) must be kept three inches from woodwork, which is three inches less than a steam pipe, though it is known that high pressure pipes attain high temperatures, always far higher than low pressure steam. It is a very awkward clause for the steam heating engineer, as a steam heating apparatus seldom has a free blow-off.—F. D.]

"The floor over any room or enclosed space in which a furnace is fixed, or any floor within eighteen inches from the crown of an oven shall be constructed of fire-resisting materials."

TABLE I.—TEMPERATURES THAT CAN BE ACQUIRED BY WATER (OR STEAM) AT CERTAIN PRESSURES (OR THE PRESSURES EXERTED BY WATER (OR STEAM) WHEN HEATED TO ABOVE 212° F. IN CONFINEMENT).—*Box.*

Pressure above the Atmosphere in lbs. per square inch.	Temperature, Fahrenheit.	Pressure above the Atmosphere in lbs. per square inch.	Temperature, Fahrenheit.
	°		°
0 (atmospheric pressure)	212	11	241
1	215	12	244
2	219	13	246
3	222	14	248
4	224	15	250
5	227	16	252
6	230	17	253
7	232	18	255
8	235	19	257
9	237	20	259
10	239	21	260

TABLE I.—*continued.*

Pressure above the Atmosphere in lbs. per square inch.	Temperature, Fahrenheit.	Pressure above the Atmosphere in lbs. per square inch.	Temperature, Fahrenheit.
	°		°
22	262	68	314
23	264	70	316
24	265	72	318
25	267	74	319
26	268	76	321
27	270	78	322
28	271	80	324
29	272	82	325
30	274	84	327
32	277	86	328
34	279	88	330
36	282	90	331
38	284	92	333
40	286	94	334
42	289	96	335
44	291	98	336
46	294	100	338
48	296	102	339
50	298	104	340
52	300	105	341
54	302	106	342
56	304	108	343
58	305	110	344
60	307	115	347
62	309	120	350
64	311	125	353
66	313	130	355

TABLE I.—*continued.*

Pressure above the Atmosphere in lbs. per square inch.	Temperature, Fahrenheit.	Pressure above the Atmosphere in lbs. per square inch.	Temperature, Fahrenheit.
	°		°
135	358	190	384
140	361	200	388
145	363	220	396
150	366	250	406
160	370	270	413
170	375	300	422
180	380		

The above table shows the pressures accompanying the high temperatures of the water in a small-bore high-pressure hot water apparatus when in use.

TABLE II.—HEIGHTS OF EQUIVALENT COLUMNS OF WATER AT DIFFERENT TEMPERATURES, THE HEIGHT AT 212° F. BEING ONE FOOT—*Box.*

Temperature of Water, Fahr.	Height of Column in inches.	Difference from 212° in inches.	Temperature of Water, Fahr.	Height of Column in inches.	Difference from 212° in inches.
°			°		
212	12·000	·000	122	11·647	·353
202	11·954	·046	112	11·611	·389
192	11·908	·092	102	11·599	·401
182	11·868	·132	92	11·570	·430
172	11·824	·174	82	11·550	·450
162	11·783	·217	72	11·532	·468
152	11·746	·254	62	11·518	·482
142	11·710	·290	52	11·508	·492
132	11·677	·323	42	11·502	·498

Amongst the uses this table may serve, is that of calculating the heights to which expansion pipes of hot water apparatus should be carried above cold water cisterns. It will be seen that water heated from 42 degrees to 212 degrees F has its column in creased ½ inch per foot.

TABLE III.—Hydraulic Memoranda.

A cubic foot of water weighs . . .	62·32 lbs.
A „ „ „ contains . . .	6·232 gals.
A „ inch „ weighs . . .	·03616 lb.
A cylindrical foot of water weighs . . .	48·96 lb.
A „ inch „ „ . . .	·0284 lb.
An imperial gallon contains	277·274 cub. in.
An „ „ „	·16046 cub. ft.
An „ „ weighs	10 lb.
A column of water 12 in. high, 1 in. square weighs	·434 lb.
A „ „ „ „ „ „ contains	·0434 gal.
A ton of water contains	35·84 cub. ft.
A „ „ „	224 gals.
Cubic feet × $6\frac{1}{4}$ (nearly exact) . . .	= gals.
Gallons × ·16	= cub. ft.
Expansion of water heated from 39° (its point of greatest condensation) to 212° . .	1 in 24
Expansion of water in freezing . . .	1 in 12

TABLE IV.—Quantities Relating to Pipes.

Size of Pipe.	Gallons per foot.	Square feet of surface in one lineal foot.	Size of Pipe.	Gallons per foot.	Square feet of surface in one lineal foot.
inches.	gallons.		inches.	gallons.	
$\frac{1}{2}$	·0084	—	3	·3056	·92
$\frac{3}{4}$	·0191	.27	4	·5433	1·17
1	·0339	·34	5	·8490	—
$1\frac{1}{4}$	·0529	·43	6	1·2226	—
$1\frac{1}{2}$	·0764	·50	8	2·1762	—
2	·1358	·62	10	3·4010	—
$2\frac{1}{2}$	·2122	·75	12	4·9	—

If the decimal point is removed one place to the right, the number will be per 10 feet; if point be removed two places to the right, the number will be per 100 feet.

A rough and ready method of estimating the contents of pipes is—square the diameter of the pipe and mark off one decimal point to give gallons in 1 yard: $4 \times 4 = 1{\cdot}6$ gal., $6 \times 6 = 3{\cdot}6$, $9 \times 9 = 8{\cdot}1$ gals.

TABLE V.—RELATIVE AREAS OF WROUGHT IRON PIPES, FROM $\frac{1}{2}$ TO 6 INCHES INCLUSIVE.

(No Allowance for Friction. This appears in the next table).

Sizes.	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4	5	6
$\frac{1}{2}$	1	$2\frac{1}{4}$	4	$6\frac{1}{4}$	9	16	25	36	64	100	144
$\frac{3}{4}$	..	1	$1\frac{7}{9}$	$2\frac{7}{9}$	4	$7\frac{1}{9}$	$11\frac{1}{9}$	16	$28\frac{1}{9}$	$44\frac{4}{9}$	64
1	..	..	1	$1\frac{9}{16}$	$2\frac{1}{4}$	4	$6\frac{1}{4}$	9	16	25	36
$1\frac{1}{4}$	..	..	..	1	$1\frac{11}{25}$	$2\frac{14}{25}$	4	$5\frac{19}{25}$	$10\frac{6}{25}$	16	$21\frac{11}{25}$
$1\frac{1}{2}$	..	..	..	..	1	$1\frac{7}{9}$	$2\frac{7}{9}$	4	$7\frac{1}{9}$	$11\frac{1}{9}$	16
2	..	..	..	..	..	1	$1\frac{9}{16}$	$2\frac{1}{4}$	4	$6\frac{1}{4}$	9
$2\frac{1}{2}$	..	..	..	..	..	..	1	$1\frac{11}{25}$	$2\frac{14}{25}$	4	$5\frac{19}{25}$
3	..	..	..	..	..	..	..	1	$1\frac{7}{9}$	$2\frac{7}{9}$	4
4	..	..	..	..	..	..	..	..	1	$1\frac{9}{16}$	$2\frac{1}{4}$
5	..	..	..	..	..	..	..	..	..	1	$1\frac{11}{25}$
6	..	..	..	..	..	..	..	..	..	..	1

This table shows at a glance the relative areas of different sized pipes. Thus, if it was required to be known how many $1\frac{1}{4}$-inch pipes have an aggregate area equal to one 3-inch pipe, it is only necessary to take the line from $1\frac{1}{4}$ inch in the left-hand column and follow it until beneath the larger size at the top of the table. The figure given, it will be seen, is nearly **6**; in other words, a 3-inch pipe of a given length carries or holds nearly six timos as much as a $1\frac{1}{4}$ inch pipe. By reversing the process, the number of small pipes that equal a large pipe can be found, the large size being found in the top column and followed down until opposite the small size in the left-hand column, Allowance for friction appears in the next table.

TABLE VI.—NUMBER OF SMALL PIPES REQUIRED TO MAKE AN AREA EQUAL TO ONE LARGER PIPE—*R. C. Carpenter.*

(With Allowance for Friction).

Size of Pipe.	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	4 in.	5 in.	6 in.
½ inch	1	2·0	3·7	7·6	11·3	19	37	55	108	188	290
¾ "	..	1	1·8	3·7	5·4	9·2	16·7	25·5	53	90	143
1 "	..	..	1	2·0	3·1	5·1	9·3	14·7	30	53	80
1¼ "	..	..	..	1	1·5	2·6	4·5	7·3	14·7	25	39
1½ "	..	..	..	..	1	1·7	3·1	4·7	9·8	16·8	26
2 "	..	..	..	..	..	1	1·83	2·9	5·8	9·9	16
2½ "	..	..	..	..	..	..	1	1·7	3·5	5·9	9·3
3 "	..	..	..	..	..	..	..	1	2·4	3·5	5·4
4 "	..	..	..	..	..	..	..	..	1	1·7	2·7
5 "	..	..	..	..	..	..	..	..	..	1	1·6
6 "	..	..	..	..	..	..	..	..	..	..	1

TABLE VII.—Pressure of Water in Cold Water Pipes.

Feet Head.	Lbs. Pressure per sq. in.	Feet Head.	Lbs. Pressure per sq. in.	Feet Head.	Lbs. Pressure per sq. in.
1	0·43	28	12·12	55	23·82
2	0·86	29	12·55	56	24·26
3	1·30	30	12·99	57	24·69
4	1·73	31	13·42	58	25·12
5	2·16	32	13·86	59	25·55
6	2·59	33	14·29	60	25·99
7	3·03	34	14·72	61	26·42
8	3·46	35	15·16	62	26·85
9	3·89	36	15·59	63	27·29
10	4·33	37	16·02	64	27·72
11	4·76	38	16·45	65	28·15
12	5·20	39	16·89	66	28·58
13	5·63	40	17·32	67	29·02
14	6·06	41	17·75	68	29·45
15	6·49	42	18·19	69	29·88
16	6·93	43	18·62	70	30·32
17	7·36	44	19·05	71	30·75
18	7·79	45	19·49	72	31·18
19	8·22	46	19·92	73	31·62
20	8·66	47	20·35	74	32·05
21	9·09	48	20·79	75	32·48
22	9·53	49	21·22	76	32·92
23	9·96	50	21·65	77	33·35
24	10·39	51	22·09	78	33·78
25	10·82	52	22·52	79	34·21
26	11·26	53	22·95	80	34·65
27	11·69	54	23·39	81	35·08

TABLE VII.—*continued.*

Feet Head.	Lbs. Pressure per sq. in.	Feet Head.	Lbs. Pressure per sq. in.	Feet Head.	Lbs. Pressure per sq. in.
82	35·52	95	41·15	108	46·78
83	35·95	96	41·58	109	47·21
84	36·39	97	42·01	110	47·64
85	36·82	98	42·45	111	48·08
86	37·25	99	42·88	112	48·51
87	37·68	100	43·31	113	48·94
88	38·12	101	43·75	114	49·38
89	38·53	102	44·18	115	49·81
90	38·99	103	44·61	116	50·24
91	39·42	104	45·05	117	50·68
92	39·85	105	45·48	118	51·11
93	40·28	106	45·91	119	51·54
94	40·72	107	46·34	120	51·98

This table is of service when calculating pressures in tanks, pipes, or boilers. A pressure of 1 lb. per square inch is obtained by a head of water of 2·31 ft., or say 2 ft. 4 in. A common practice is to allow 1 lb. for every 2-ft. head, which admits of quick calculation, and what error is made is on the right side. Thus, a 30-ft. head would be said to afford a pressure of 15 lbs. to the square inch, but the correct pressure would be 13 lbs. only.

The size of pipe makes no difference to the pressure, nor does the size of the cistern which may be at the head of the pipe. In ascertaining pressure, the perpendicular measurement is taken from the level of water in the cistern to the point where the pressure is to be experienced, and, as stated, 0·43 lb. pressure is allowed to each foot, or 2 ft. 4 in. to the pound.

TABLE VIII.

The Quantity of Water that Air is capable of Absorbing to become Saturated.

Deg. Fahr.	Grains per Cubic Foot.	Deg. Fahr.	Grains per Cubic Foot.	Deg. Fahr.	Grains per Cubic Foot.	Deg. Fahr.	Grains per Cubic Foot.
10	1	45	$3\frac{5}{8}$	85	$12\frac{1}{2}$	141	58
15	$1\frac{1}{3}$	50	$4\frac{1}{4}$	90	$14\frac{1}{3}$	157	85
20	$1\frac{1}{2}$	55	5	95	$16\frac{5}{8}$	170	$112\frac{1}{2}$
25	$1\frac{7}{8}$	60	$5\frac{7}{8}$	100	$19\frac{1}{8}$	179	138
30	$2\frac{1}{8}$	65	$6\frac{7}{8}$	105	22	188	166
32	$2\frac{1}{3}$	70	8	110	$25\frac{1}{2}$	195	194
35	$2\frac{1}{2}$	75	$9\frac{1}{4}$	115	30	212	265
40	3	80	$10\frac{3}{4}$	130	$42\frac{1}{2}$		

This table shows the necessity of affording moisture to air which is warmed to comparatively high temperatures, as with hot air works; it also shows what a high degree of efficiency hot air has in drying rooms (provided it is extracted and replaced with new as fast as it becomes saturated).

A convenient means of judging the humidity of the air is by the dry and wet bulb hygrometer, as it is called. This consists of a pair of thermometers, one of which acts in the usual way, this being the dry bulb, while the other is covered with muslin and kept wet by a piece of material extending from the muslin to a small vessel of water. The water travels up this material by capillary attraction. The water in the muslin on the thermometer bulb is continually evaporating, and the degree of evaporation is according to the dryness of the air. As the water evaporates it has a cooling effect on the bulb, and the temperature recorded by the height of the mercury in the stem varies with that in the dry thermometer accordingly. The greater the difference the more dry the air must be, and in a case of extreme dryness a difference of 20 degrees might possibly be indicated. A healthful and proper degree of humidity is when the thermometers show a difference of 6 or 8 degrees, the wet bulb showing the lowest temperature, of course. A difference of 10 degrees indicates dryness, too dry in fact, though not excessively so.

TABLE IX.

Heat-Conducting Power of Materials (Comparative).

Copper	515	Gutta-percha	1·38
Iron	233	India-rubber	1·37
Zinc	225	Brick dust, fine	1·33
Lead	113	Coke dust	1·29
Marble, fine-grained	28	Cork	1·15
„ coarse-grained	22·4	Chalk, powdered	·869
Stone, fine	16·7	Straw, chopped	·563
„ ordinary	13·68	Coal dust	·547
Glass	6·6	Wood ashes	·531
Bricks	4·83	Sawdust, mahogany	·523
Plaster	3·86	Canvas, new	·418
Oak, across the grain	1·70	Calico „	·402
Walnut „	·83	White writing paper	·346
Fir „	·748	Cotton wool or sheep's wool, any density	·328
„ with the grain	1·37	Eider down	·314
Walnut „	1·40		

Resistance to Conductivity.

Felt	1·000	Gas-house carbon	·570
Silicate cotton	·832	Asbestos	·363
Sawdust	·686	Coal ashes	·343
Pine wood	·553		

These tables are of use in showing the loss of heat that can occur from pipes and other surfaces, and the efficiency of the various materials used to prevent loss of heat.

TABLE X.

Tests of Various Pipe Coverings, made at Sibley College, Cornell University, *by Professor R. C. Carpenter.*

Kind of Covering.	Relative Amount of Heat transmitted.
Naked pipe	100
Two layers asbestos paper, 1 inch hair felt and canvas cover	15·2
„ „ 1 inch hair felt, canvas cover, wrapped with manilla paper	15·0
„ „ 1 inch hair felt	17·0

TABLE X.—*continued.*

Kind of Covering.	Relative Amount of Heat transmitted.
Hair felt sectional covering, asbestos lined	18·6
One thickness asbestos board	59·4
Four thicknesses asbestos paper	50·3
Two layers asbestos paper	77·7
Wool felt, asbestos lined	23·1
„ with air spaces, asbestos lined	19·7
„ plaster of Paris lined	25·9
Asbestos moulded, mixed with plaster of Paris	31·8
„ felted, pure long fibre	20·1
„ and sponge	18·8
„ and wool felt	20·8
Magnesia, moulded, applied as a plaster	22·4
„ sectional	18·8
Silicate cotton (slag wool) sectional	19·3
Rock wool, fibrous	20·3
„ felted	20·9
Fossil meal, ¾ inch thick	29·7
Pipe painted with black asphalt	105·5
„ „ light drab lead paint	108·7
Glossy white paint	95·0

Much information is afforded by this series of tests. It shows conclusively that although we have distinctly good and bad conductors of heat, their efficiency in these respects depends very greatly on conditions. Materials applied loosely act as barriers of heat much better than the same substances tightly bound on, or ground up and plastered on. Hair felt, which the writer considers the most successful material in conserving heat, owes much to its being made up in a semi-loose state, much as nature puts the hair on the skins of animals. The felt consists more of air interstices than it does of hair, and were it ground up and plastered on the heated surface its effectiveness could not fail to be largely diminished.

These tests also show what has been referred to in this book when treating of the efficiency of radiators, that paint has practically no effect in spoiling the heat-distributing power of the iron, but in some cases actually improves it. It may be considered that paints can be safely used on radiating surfaces, irrespective of the colour required.

TABLE XI.—Ventilating Gratings or Registers.

Table giving the average Clear Space through Gratings, *i.e.* the Area of the Grating minus the Iron Bars or Fretwork.

Size of Grated Area in square inches.	Clear Space in square inches.	Size of Grated Area in square inches.	Clear Space in square inches.	Size of Grated Area in square inches.	Clear Space in square inches.
4 × 6	16	8 × 15	80	12 × 24	192
4 × 8	21	8 × 18	96	14 × 14	130
4 × 10	26	9 × 9	54	14 × 16	149
4 × 13	34	9 × 12	72	14 × 18	168
4 × 15	40	9 × 13	78	14 × 20	186
4 × 18	48	9 × 14	84	14 × 33	205
6 × 6	24	10 × 10	66	15 × 25	250
6 × 8	32	10 × 12	80	16 × 16	170
6 × 9	36	10 × 14	93	16 × 20	213
6 × 10	40	10 × 16	107	16 × 24	256
6 × 14	56	10 × 18	120	18 × 24	288
6 × 16	64	10 × 20	132	20 × 20	267
6 × 18	72	12 × 12	96	20 × 24	320
6 × 24	96	12 × 14	112	20 × 26	347
7 × 7	32	12 × 15	120	24 × 24	384
7 × 10	52	12 × 16	128	24 × 32	512
8 × 8	42	12 × 17	136	27 × 27	486
8 × 10	53	12 × 18	144	30 × 30	600
8 × 12	64	12 × 20	160		

The solid flange, or margin, that all gratings have is not included in any of the above measurements.

TABLE XII.

Equivalent Value of Units in English and Metrical Measurements.

One foot = 12 inches = 30·48 centimetres = 0·3048 metre.

One metre = 100 centimetres = 3·2808 feet = 1·0936 yard.

One mile = 5280 feet = 1760 yards = 1609·3 metres.

One square foot = 144 square inches = $\frac{1}{9}$th square yard = 929 square centimetres = 0·0929 square metre.

One square metre = 10,000 square centimetres = 1·1960 square yards = 10·764 square feet.

One cubic foot = 1728 cubic inches = 2832 cubic centimetres = 0·02832 cubic metres.

One cubic metre = 35·314 cubic feet = 1·3079 cubic yard.

One pound = 16 ounces = 453·59 grams = 0·45359 kilogram.

One kilogram = 1000 grams = 2·2046 pounds = 35·27 ounces.

For Conversion of Metrical to English Measurement.

Millimetres	×	·03937	=	inches.
„	÷	25·4	=	„
Centimetres	×	·3937	=	„
„	÷	2·54	=	„
Metre	=	39·37 inches.		
„	×	3·281	=	feet.
„	×	1·094	=	yards.
Kilometres	×	·621	=	miles.
„	÷	1·6093	=	„
„	×	3280·7	=	feet.
Square millimetres	×	·0155	=	square inches.
„ „	÷	645·1	=	„
„ centimetres	×	·155	=	„
„ „	÷	6·451	=	„
„ metres	×	10·764	=	square feet.
„ kilometres	×	247·1	=	acres.
Hectares	×	2·471	=	„
Cubic centimetres	÷	16·383	=	cubic inches.

TABLE XIII.—CORRESPONDING DEGREES OF THE CENTIGRADE AND FAHRENHEIT THERMOMETERS.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
+ 220 =	+ 428	+ 95 =	+ 203	+ 67 =	+ 152·6
215 =	419	94 =	201·2	66 =	150·8
210 =	410	93 =	199·4	65 =	149
205 =	401	92 =	197·6	64 =	147·2
200 =	392	91 =	195·8	63 =	145·4
195 =	383	90 =	194	62 =	143·6
190 =	374	89 =	192·2	61 =	141·8
185 =	365	88 =	190·4	60 =	140
180 =	356	87 =	188·6	59 =	138·2
175 =	347	86 =	186·8	58 =	136·4
170 =	338	85 =	185	57 =	134·6
165 =	329	84 =	183·2	56 =	132·8
160 =	320	83 =	181·4	55 =	131
155 =	311	82 =	179·6	54 =	129·2
150 =	302	81 =	177·8	53 =	127·4
145 =	293	80 =	176	52 =	125·6
140 =	284	79 =	174·2	51 =	123·8
135 =	275	78 =	172·4	50 =	122
130 =	266	77 =	170·6	49 =	120·2
125 =	257	76 =	168·8	48 =	118·4
120 =	248	75 =	167	47 =	116·6
115 =	239	74 =	165·2	46 =	114·8
110 =	230	73 =	163·4	45 =	113
100 =	212	72 =	161·6	44 =	111·2
99 =	210·2	71 =	159·8	43 =	109·4
98 =	208·4	70 =	158	42 =	107·6
97 =	206.6	69 =	156·2	41 =	105·8
96 =	204·8	68 =	154·4	40 =	104

TABLE XIII.—*continued.*

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
+ 39 =	+ 102·2	+ 19 =	+ 66·2	+ 0 =	+ 32
38 =	100·4	18 =	64·4	− 1 =	30·2
37 =	98·6	17 =	62·6	2 =	28·4
36 =	96·8	16 =	60·8	3 =	26 6
35 =	95	15 =	59·0	4 =	24·8
34 =	93·2	14 =	57·2	5 =	23
33 =	91·4	13 =	55·4	6 =	21·2
32 =	89·6	12 =	53·6	7 =	19·4
31 =	87·8	11 =	51·8	8 =	17·6
30 =	86	10 =	50	9 =	15·8
29 =	84·2	9 =	48·2	10 =	14
28 =	82·4	8 =	46·4	11 =	12·2
27 =	80·6	7 =	44·6	12 =	10·4
26 =	78·8	6 =	42·8	13 =	8·6
25 =	77	5 =	41	14 =	6·8
24 =	75·2	4 =	39·2	15 =	5
23 =	73·4	3 =	37·4	16 =	3·2
22 =	71·6	2 =	35·6	17 =	1·4
21 =	69·8	1 =	33·8	18 =	− 0·4
20 =	68				

The following rule can be adopted for converting one thermometric scale into another :—

Cent.	degrees	$\div 5 \times 9 + 32$	= Fahr. degrees.
„	„	$\div 5 \times 4$	= Réaumur „
Fahr.	„	$- 32 \div 9 \times 5$	= Cent. „
„	„	$- 32 \div 9 \times 4$	= Réaumur „
Réaumur	„	$\div 4 \times 9 + 32$	= Fahr. „
„	„	$\div 4 \times 5$	= Cent. „

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